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Analysis of Risk Factors Associated with Pulmonary Tuberculosis Incidence in the Working Area of Caile Community Health Center, Bulukumba Regency

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ABSTRACT

Pulmonary tuberculosis (TB) is an infectious disease caused by Mycobacterium tuberculosis that attacks the lungs and bronchi. This disease is transmitted through the air. This study aimed to determine the risk factors associated with the incidence of pulmonary TB in the working area of Caile Community Health Center, Bulukumba Regency. This research used an analytical observational design with a case-control approach. The sampling technique was total sampling, with a total of 96 respondents consisting of 48 cases and 48 controls. Data were collected in March 2025. The majority of respondents were aged 50–59 years, and most were male. Data collection techniques included interviews and observations. Data were analyzed using univariate, bivariate (chi-square test), and multivariate (logistic regression) analyses.. The results showed a significant relationship between occupancy density (p = 0.001), ventilation area (p = 0.001), humidity (p = 0.002), and contact history (p = 0.001) with the incidence of pulmonary TB. Although smoking status showed no significant association in the bivariate analysis (p = 0.066), it became statistically significant in the multivariate model after controlling for confounding variables. Multivariate analysis also showed that the most dominant risk factor was contact history, with an OR value of 28.569, indicating that individuals with a history of contact with pulmonary TB patients were 28.5 times more likely to develop the disease..The study concludes that of the five variables analyzed, four were identified as risk factors for pulmonary TB incidence, with contact history being the most dominant. Efforts to prevent and control pulmonary TB should focus on improving housing conditions, enhancing ventilation quality, maintaining appropriate humidity, providing education on the dangers of smoking, and emphasizing the importance of avoiding direct contact with pulmonary TB patients, as well as strengthening contact screening by health workers.

Keywords : Pulmonary TB, Contact History, Residential Density, Ventilation Area, Humidity

INTRODUCTION

Tuberculosis (TB) remains a major global health issue with high morbidity and mortality rates. The disease is caused by Mycobacterium tuberculosis, which is transmitted through the air when infected individuals release droplets while coughing or sneezing. TB generally affects the lung parenchyma (Pulmonary TB), but it can also infect other organs (Extrapulmonary TB), such as the pleural membrane, lymph nodes, bone structures, and various other extrapulmonary organs.[1] WHO data show an increasing trend of global TB cases in the last three years, from 5.3 million cases in 2021 to 6.9 million cases in 2023. Indonesia ranks second after India as the largest contributor of new TB cases, with an incidence rate of 385 per 100,000 population in 2022, up from 354 per 100,000 in the previous year.[2]

At the national level, South Sulawesi ranks 7th among provinces with the highest number of Pulmonary TB cases, recording 25,761 cases in 2023.[4] In Bulukumba District, cases have increased from 651 in 2019 to 837 in 2023. This upward trend indicates the widespread transmission of Pulmonary TB in the area, including in the working area of Caile Primary Health Center (Puskesmas), which reported 60 new cases between January and October 2024, up from 27 cases in 2023. This condition reflects the ongoing wide spread of Pulmonary TB that requires serious attention.

Previous studies have shown that sociodemographic, environmental, behavioral, and health-related factors play a role in increasing the risk of Pulmonary TB. Sociodemographic factors include being male, age, education level, marital status, low income, unemployment, and body mass index (BMI) in the underweight category. Environmental aspects include poor household ventilation, housing density, high humidity, and low sunlight exposure.[5] Research by Sipayung et al. (2023) revealed that housing density, ventilation systems, humidity levels, as well as the condition of floors and walls are key factors influencing Pulmonary TB occurrence. In fact, households with more occupants than the standard requirement have a 13 times higher risk compared to those meeting the standard.[7] Other studies also emphasized that inadequate ventilation and high humidity are significantly associated with Pulmonary TB due to poor air circulation that facilitates the growth of Mycobacterium tuberculosis.[8] Moreover, a history of household contact with Pulmonary TB patients and smoking behavior have been proven to increase vulnerability to TB infection.[9]

Preliminary observations indicate that the working area of Caile Primary Health Center is one of the locations with persistently high and increasing Pulmonary TB cases. However, no previous study in this region

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has simultaneously analyzed environmental factors such as humidity and ventilation together with behavioral factors like contact history and smoking. This makes the present study the first to comprehensively examine these combined risk factors in the Caile Health Center area.

The selection of Caile as the study site is based on its status as one of the areas with the highest and consistently increasing numbers of Pulmonary TB cases in Bulukumba District, along with the complete absence of prior local research exploring the specific determinants of transmission. Investigating this location is therefore crucial to provide evidence-based insights for local TB control efforts and to better understand the potential causes behind the suspected local outbreak pattern.

Therefore, this study aims to analyze the risk factors contributing to the spread of Pulmonary TB in Bulukumba District, with a focus on Caile Primary Health Center as the area with the highest number of cases. The research variables include housing density, ventilation size, humidity, contact history, and smoking status. The findings of this study are expected to serve as a basis for formulating more effective prevention and control strategies, as well as to support public health improvement efforts in Bulukumba District, particularly in Caile Primary Health Center.

MATERIAL AND METHOD

This study was an analytical observational research employing a case–control design. The case group included all confirmed Pulmonary Tuberculosis (TB) patients recorded in the SITB (Tuberculosis Information System) from January to October 2024 within the working area of Caile Primary Health Center, while the control group consisted of community members without Pulmonary TB. The total sampling technique was applied, yielding 96 respondents divided equally into 48 cases and 48 controls. The independent variables were housing density, ventilation size, humidity, contact history, and smoking status, while the dependent variable was the incidence of Pulmonary TB.

Samples were selected using a non-probability total sampling approach with a 1:1 case-to-control ratio. The case group comprised individuals diagnosed with Pulmonary TB and registered in Caile Health Center medical records, who consented to participate and allowed household observation. Exclusion criteria included patients who had recovered, defaulted, or died. The control group consisted of neighbors living adjacent to TB patients who had never been diagnosed with TB and consented to participate and observation.

Data were collected through structured interviews using a standardized questionnaire and direct field observation. Ventilation area was measured using a tape measure, while humidity was recorded using a digital hygrometer. Data analysis was performed in three stages: univariate analysis, bivariate analysis using the chi-square test, and multivariate analysis using multiple logistic regression to identify the most dominant factors associated with Pulmonary TB incidence.

RESULT

This study was conducted in the working area of Caile Primary Health Center, Bulukumba Regency, with data collection carried out in March 2025 and a total sample of 96 respondents. After the data were analyzed and processed according to the study objectives, the following results were obtained:

Univariate Analysis

Table 1. Distribution of Pulmonary TB Respondents in the Working Area of Caile Primary Health Center, Bulukumba Regency, 2025

Characteristics	Total (n)
Gender	
Male	54
Female	42
Age	
20-29 Years	10
30-39 Years	24
40-49 Years	21
50-59 Years	30
60-69 Tahun	9
70-79 Tahun	2

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Characteristics	Total (n)
Education	
Elementary school or equivalent	16
Junior high school or equivalent	22
Senior high school or equivalent	40
Higher education	18
Occupation	
Unemployed	9
Trader	13
Entrepreneur	14
Civil servant	5
Housewife	21
Farmer	5
Laborer	8
Fisherman	21

Source: Primary Data, 2025

From Table 1, the characteristics of respondents by sex show that out of 96 respondents, 54 (56.3%) were male and 42 (43.8%) were female. By age group, the 50–59-year group represented the highest number of pulmonary TB cases, with 30 respondents (31.3%). Conversely, the lowest incidence was found in the 70–79-year group, with only 2 respondents (2.1%). Regarding education, 16 respondents (16.7%) had elementary education, 22 (22.9%) junior high, 40 (41.7%) senior high, and 18 (18.8%) higher education. By occupation, the majority were fishermen and housewives, each with 21 respondents (21.9%), while the smallest groups were civil servants and farmers, each with 5 respondents (5.2%).

Bivariate Analysis

Table 2. Association Between Housing Density and Pulmonary TB Incidence in the Working Area of Caile Primary Health Center, Bulukumba Regency, 2025

Housing Density	Pulmonary TB Incidence				*p value*	OR (95% CI)
	Case		Control			
	n	%	n	%		
Did not meet requirements	40	83,3	12	25,0	0,001	15,000 (5,510-40,836)
Meet requirements	8	16,7	36	75,0		
Total	48	100	48	100		

Source: Primary Data, 2025

From Table 2, respondents with inadequate housing density were mostly found in TB cases (40 respondents, 83.3%) compared to controls (12 respondents, 16.7%). Conversely, respondents with adequate housing density were more common in the control group (36 respondents, 75.0%) than in cases (8 respondents, 25.0%). The Chi-square test showed a significant association ($p = 0.001 < 0.05$), with an odds ratio (OR) of 15.000, indicating that housing density significantly influenced pulmonary TB incidence.

Table 3. Association Between Ventilation Size and Pulmonary TB Incidence in the Working Area of Caile Primary Health Center, Bulukumba Regency, 2025

Ventilation Size	Pulmonary TB Incidence				*p value*	OR (95% CI)
	Case		Control			
	n	%	n	%		
Did not meet requirements	35	72,9	12	25,0	0,001	8,077 (3,244-20,110)
Meet requirements	13	27,1	36	75,0		
Total	48	100	48	100		

Source: Primary Data, 2025

Table 3 shows that respondents with inadequate ventilation were more common among TB cases (35 respondents, 72.9%) than controls (12 respondents, 25.0%). Adequate ventilation was dominant in the control group (36 respondents, 75.0%). The Chi-square test showed a significant association ($p = 0.001 < 0.05$), with an OR of 8.077, confirming that ventilation size significantly influenced pulmonary TB incidence.

Vol. XX No. 2 Desember 2025
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Table 4. Association Between Humidity and Pulmonary TB Incidence in the Working Area of Caile Primary Health Center, Bulukumba Regency, 2025

Humidity	Pulmonary TB Incidence				*p value*	OR (95% CI)
	Case		Control			
	n	%	n	%		
Did not meet requirements	32	66,7	17	35,4	0,002	3,647 (1,570-8,470)
Meet requirements	16	33,3	31	64,6		
Total	48	100	48	100		

Source: Primary Data, 2025

Table 4 indicates that inadequate humidity was more frequent among TB cases (32 respondents, 66.7%) than controls (17 respondents, 35.4%). Adequate humidity was more common in controls (31 respondents, 64.6%). The Chi-square test showed a significant association ($p = 0.002 < 0.05$), with an OR of 3.647, indicating humidity had a significant effect on TB incidence.

Table 5. Association Between Contact History and Pulmonary TB Incidence in the Working Area of Caile Primary Health Center, Bulukumba Regency, 2025

Contact History	Pulmonary TB Incidence				*p value*	OR (95% CI)
	Case		Control			
	n	%	n	%		
With contact history	41	85,4	17	35,4	0,001	10,681 (3,944-28,922)
No contact history	7	14,6	31	64,6		
Total	48	100	48	100		

Source: Primary Data, 2025

From Table 5, the majority of respondents with a history of contact with TB patients were found in the case group (41 respondents, 85.4%), while only 17 respondents (35.4%) in the control group had contact history. Conversely, those without contact history were more common among controls (31 respondents, 64.6%). The Chi-square test showed a significant association ($p = 0.001 < 0.05$), with an OR of 10.681, meaning contact history significantly influenced pulmonary TB incidence.

Table 6. Association Between Smoking Status and Pulmonary TB Incidence in the Working Area of Caile Primary Health Center, Bulukumba Regency, 2025

Smoking Status	Pulmonary TB Incidence				*p value*	OR (95% CI)
	Case		Control			
	n	%	n	%		
Smoker	30	62,5	21	43,8	0,066	2,143 (0,947-4,848)
No Smoker	18	37,5	27	56,3		
Total	48	100	48	100		

Source: Primary Data, 2025

Table 6 shows no significant association between smoking status and pulmonary TB incidence ($p = 0.066 > 0.05$). Among cases, 30 respondents (62.5%) smoked, compared to 21 respondents (43.8%) in controls. Non-smokers were more common in controls (27 respondents, 56.3%). Although smokers showed a 2.1 times higher risk, the confidence interval included 1, meaning the association was not statistically significant.

Multivariate Analysis

Table 7. Logistic Regression Results of Risk Factors Associated with Pulmonary TB Incidence in the Working Area of Caile Primary Health Center, Bulukumba Regency, 2025

Variable	*p value*	OR	95 % CI
Housing density	0,001	29,204	5,544 - 153,837
Ventilation Size	0,003	12,186	2,392 - 62,085
Humidity	0,034	5,503	1,140 - 26,572
Contact history	0,001	52,859	7,359 - 379,661
Smoking Status	0,013	7,603	1,546 - 37,395

Source: Primary Data, 2025

Vol. XX No. 2 Desember 2025
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Based on Table 7, the results of multivariate analysis using multiple logistic regression showed that after controlling for other variables, all factors (housing density, ventilation size, humidity, contact history, and smoking status) had significant associations with pulmonary TB incidence in the working area of Caile Primary Health Center, Bulukumba Regency. Among these, contact history had the greatest influence, with a p-value of 0.001 ($p < 0.05$) and an OR of 52.859, indicating that individuals with a history of contact with pulmonary TB patients were 52.8 times more likely to develop TB compared to those without such contact.

DISCUSSION

The Relationship between Housing Density and the Incidence of Pulmonary TB in the Working Area of Caile Primary Health Center, Bulukumba District

Housing density is a physical environmental factor of the household that plays an important role in increasing the risk of respiratory infectious diseases, including Pulmonary TB. Overcrowding occurs when the size of the house is not proportional to the number of occupants, thereby obstructing air circulation and oxygen supply within the household. Such conditions facilitate the spread of disease, especially when a family member is infected with Pulmonary TB, thus significantly increasing the likelihood of transmission to other family members living in the same house.[6]

Findings of this study indicate a significant relationship between housing density and the prevalence of Pulmonary TB in the working area of Caile Primary Health Center, Bulukumba District. Individuals living in overcrowded households beyond the standard requirement were found to have 15 times higher probability of contracting Pulmonary TB compared to those living in households that met the standard. This indicates that densely populated housing conditions are a risk factor that enhances the spread of Pulmonary TB. The denser the occupancy, the greater the potential for TB transmission within the household.

Field observations revealed that compliance with the housing space standard (≥ 9 m² per person) was rarely achieved, primarily due to two reinforcing factors: a large number of household members and relatively small house sizes. Most houses in the working area of Caile Primary Health Center were occupied by extended families, consisting of multiple generations such as children, parents, and grandparents living in the same dwelling. As a result, rooms such as bedrooms, living rooms, or family rooms were shared by several individuals at once, thereby exceeding the ideal occupancy standard.

This condition was generally found among low-income families, particularly among Pulmonary TB patients, most of whom worked as fishermen and housewives with irregular income. Economic limitations directly affected the inadequacy of the physical housing conditions, leaving families unable to renovate or expand their living spaces to create a healthier environment. Consequently, residents had limited space to carry out activities, rest, or maintain physical distance, resulting in restricted movement, poor air circulation, and close proximity among household members, all of which increased the risk of Mycobacterium tuberculosis transmission.

In overcrowded homes, where the number of occupants is disproportionate to the size of the dwelling, the risk of Pulmonary TB transmission becomes much higher.[6] Transmission occurs through microscopic droplets released when patients cough or sneeze. These droplets are easily inhaled by others, particularly in densely populated homes with inadequate ventilation, thereby accelerating household infection spread.[10] Increased occupancy also affects indoor air quality, leading to reduced oxygen levels, higher humidity, increased temperature, and elevated carbon dioxide (CO_2) concentration. These conditions create an environment conducive to the survival of airborne Mycobacterium tuberculosis.[11]

These findings are consistent with the study of Vianitati & Nona Fembi (2022), which reported a significant relationship between housing density and Pulmonary TB incidence ($p = 0.000$). Similarly, Muhajirin et al. (2022) reported a significant result ($p = 0.031$), showing that respondents living in overcrowded homes had a ninefold higher risk of Pulmonary TB. Furthermore, Sari et al. (2022) found a significant correlation ($p = 0.000$), where households with overcrowding had a 21.77-fold higher risk of TB infection compared to households meeting the standard. These findings reinforce the role of housing conditions as a crucial factor in TB transmission.

This study confirms that housing density is one of the environmental factors significantly associated with Pulmonary TB incidence. High housing density increases the risk of transmission due to close contact and poor air circulation. Therefore, active involvement from multiple stakeholders, including health centers and communities, is required to address this issue comprehensively.

The Relationship between Ventilation Size and the Incidence of Pulmonary TB in the Working Area of Caile Primary Health Center, Bulukumba District

Ventilation is the mechanism of air exchange in a room aimed at bringing in fresh air and removing contaminated air. The ventilation size of a house refers to the total surface area designed to facilitate air circulation between the indoor and outdoor environments. Ventilation standards are usually determined based on a proportion

Vol. XX No. 2 Desember 2025
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of floor or wall area. Adequate ventilation helps maintain indoor air quality, reduce humidity, and prevent the accumulation of pollutants or pathogenic microorganisms.[8]

This study confirmed a significant relationship between ventilation size and Pulmonary TB incidence in the working area of Caile Primary Health Center, Bulukumba District. Findings indicated that individuals living in houses with substandard ventilation had up to eight times higher risk of developing Pulmonary TB compared to those living in houses with adequate ventilation. This highlights that inadequate ventilation is a risk factor contributing to TB transmission.

Field observations revealed that most Pulmonary TB households had insufficient ventilation. Some had no ventilation at all. In houses that did have ventilation, it was often obstructed by partitions such as boards, cloths, or furniture that blocked airflow. Such barriers disrupted fresh air entry, resulting in poor air exchange. Consequently, rooms became humid, hot, and stuffy, with limited fresh air circulation. Moreover, blocked ventilation restricted sunlight penetration, which is crucial for suppressing the growth of pathogenic microorganisms, including TB-causing bacteria. The situation was worsened by household habits of rarely opening windows, thereby preventing natural air circulation and reducing natural lighting, creating dark and damp environments favorable for MTB survival.

Additionally, densely populated settlements with houses built very close together sometimes separated only by thin walls or narrow alleys limited cross-ventilation. Homes with high occupancy and tightly packed structures typically had poor airflow due to obstruction by surrounding buildings, further deteriorating indoor air quality and allowing airborne bacteria to persist longer indoors. Poor ventilation also increases indoor humidity, creating an environment that supports MTB survival and growth. Conversely, good ventilation improves indoor air quality, reducing the risk of allergies, asthma, and other respiratory illnesses.[14]

These findings are consistent with Susanto Sipayung et al. (2023), who identified a significant association between ventilation size and Pulmonary TB incidence ($p = 0.038$). In that study, houses with inadequate ventilation showed a 2.39-fold higher risk of Pulmonary TB compared to those with adequate ventilation. Similarly, Mauliyana Andi & Hadrikaselma Evi (2021) reported a significant association ($p = 0.019$), where individuals living in homes with inadequate ventilation were three times more likely to develop TB than those in adequately ventilated homes.

Interventions that can be implemented include regularly opening windows, rearranging room layouts to improve air circulation, and enlarging ventilation openings when possible. Primary health centers play an essential role in educating communities on the importance of adequate home ventilation, particularly in households with TB patients or individuals showing symptoms.

The Relationship between Humidity and the Incidence of Pulmonary TB in the Working Area of Caile Primary Health Center, Bulukumba District

Humidity refers to the amount of water vapor in the air, usually measured as a percentage. Indoor humidity is an important indicator of physical environmental quality that can influence the risk of respiratory infections, including Pulmonary TB. High humidity levels may cause drying of the nasal mucosa, reducing its ability to block microorganisms.[16]

This study found a significant association between humidity and Pulmonary TB incidence in the working area of Caile Primary Health Center, Bulukumba District. Findings indicated that individuals living in homes with humidity levels outside the recommended range had a 3.6-fold higher risk of developing Pulmonary TB compared to those living in homes with normal humidity. Humid air slows the evaporation of droplets, allowing infectious particles to remain suspended in indoor air longer, thus creating an environment conducive to MTB transmission.

Field observations revealed that indoor humidity levels among Pulmonary TB households generally exceeded 60%, which is above the standard for healthy housing. Excess humidity was primarily caused by inadequate ventilation. Most houses had limited openings and rarely opened windows, allowing moisture from daily activities such as bathing and cooking to become trapped indoors. This resulted in damp and stuffy conditions, restricted fresh air circulation, and prolonged persistence of droplets released during coughing or sneezing by TB patients.

Geographical factors also contributed to high humidity levels, as the Caile Primary Health Center is located in a coastal area. Coastal regions naturally maintain high humidity year-round, even during the dry season. This was further aggravated by fluctuating weather patterns—hot temperatures during the day followed by rainfall in the evening which caused rapid shifts in indoor humidity and temperature. These conditions were exacerbated in densely populated neighborhoods with closely packed houses lacking proper ventilation.

Humid indoor environments, particularly with humidity levels above 70%, provide favorable conditions for droplets containing Mycobacterium tuberculosis to persist in the air or settle on surfaces. Under such conditions, the bacteria survive longer and have greater potential to infect household members, especially in enclosed, dark, and overcrowded rooms. Conversely, when exposed to direct sunlight, MTB survival is reduced. Thus, houses with high humidity levels may serve as ideal settings for Pulmonary TB transmission.

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These findings align with Susanto Sipayung et al. (2023), who reported a significant correlation between humidity levels and Pulmonary TB incidence (p = 0.008), where non-standard humidity conditions were associated with a 3.08-fold higher risk of TB compared to standard conditions. Similarly, Dewi et al. (2024) reported a significant association (p = 0.039), further supporting the link between indoor humidity and Pulmonary TB. As a preventive measure, primary health centers play an important role in educating the public on maintaining indoor humidity within the recommended range of 40–60%. This can be achieved through healthy housing education programs, home visits by health promotion officers, and community health workers actively disseminating information on household environments that support TB prevention.

The Relationship between Contact History and the Incidence of Pulmonary TB in the Working Area of Caile Primary Health Center, Bulukumba District

Contact history refers to direct interaction or physical contact with someone diagnosed with Pulmonary TB. Transmission of various pathogens, including Mycobacterium tuberculosis, may occur through touch or droplets expelled when a patient coughs or sneezes.[18] Contact history plays a significant role in the transmission of Pulmonary TB, especially among families living in the same household or in close proximity, with frequent interactions with TB patients.[19]

This study found a significant relationship between contact history and Pulmonary TB incidence in the working area of Caile Primary Health Center, Bulukumba District. Individuals who had direct contact with a person diagnosed with Pulmonary TB were 10.6 times more likely to be infected compared to those without such contact.

Field observations and interviews revealed that most Pulmonary TB patients interacted with family members who were currently or previously diagnosed with TB. These contacts generally occurred in crowded houses with poor air circulation, where no separation was made between sick and healthy family members. Most respondents lived in the same house with TB patients, even sharing bedrooms and dining utensils without specific preventive measures.

Additionally, most respondents lived in permanent stone houses with tightly sealed structures and inadequate ventilation, limiting air exchange. These houses were located in dense settlements, with narrow indoor spaces and multiple family members sharing the same dwelling. Such conditions facilitated close social interactions among residents, not only within households but also with nearby neighbors through visits, conversations in narrow yards, or use of shared spaces. This broadened the scope of exposure beyond family members to include neighbors with close contact.

Furthermore, most Pulmonary TB patients were aged 30–59 years, a productive age group with high mobility and frequent social interactions, which increased the risk of exposure to Mycobacterium tuberculosis in the community.[20]

In terms of occupation, most respondents were fishermen or housewives. Fishermen face higher risks of respiratory infections, including Pulmonary TB, due to exposure to dust, boat engine smoke, high humidity, and lack of respiratory protection. Their long and irregular working hours may also weaken the immune system due to fatigue and lack of rest. These risks are compounded by living in overcrowded homes with poor ventilation, common in coastal areas with limited access to healthy housing. Meanwhile, housewives were also at higher risk because they spent more time at home, increasing the likelihood of prolonged close contact with infected family members. The risk was exacerbated in poorly ventilated and humid houses, where Mycobacterium tuberculosis survives longer in the air.[21]

These findings are consistent with Mauliyana Andi & Hadrikaselma Evi (2021), who found a correlation between contact history and Pulmonary TB incidence (p = 0.000), with individuals exposed to TB patients being 8.3 times more likely to contract the disease. Similarly, Azzahra et al. (2024) reported a significant association (p = 0.000), showing that individuals with contact history had a 7.6-fold higher risk compared to those without contact.

This indicates that households are one of the main centers of TB transmission, highlighting the need for comprehensive interventions. Primary health centers and community health workers play an essential role in household contact screening, early detection of at-risk family members, and education on preventive behaviors such as cough etiquette, mask use, and temporary isolation for active TB patients.

The Relationship between Smoking Status and the Incidence of Pulmonary TB in the Working Area of Caile Primary Health Center, Bulukumba District

Smoking behavior impairs the effectiveness of several protective mechanisms in the respiratory system. Tobacco smoke slows ciliary activity and stimulates mucus secretion, leading to mucus buildup and increased risk of pathogenic microorganism growth. Environments exposed to cigarette smoke may hinder Pulmonary TB recovery, especially when smoking occurs indoors. Such exposure weakens the immune system, particularly the respiratory defenses, thereby increasing the risk of infection.[22]

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This study found that smoking status was not significantly associated with Pulmonary TB incidence in the working area of Caile Primary Health Center, Bulukumba District (p = 0.066), although a trend toward increased risk was observed. Proportionally, smokers were more common in the case group than in the control group, but the difference was not statistically strong enough to prove an association.

The absence of a significant correlation may be influenced by sample size limitations and the predominance of male respondents. This is consistent with TB prevalence data in South Sulawesi Province in 2023, showing that TB cases were more frequent in men (60.1%) compared to women (39.9%).[4] Men are more likely to engage in outdoor activities and work in high-risk environments, increasing their chance of contact with active TB patients. Moreover, as smoking is more prevalent among men, its high proportion in both case and control groups may have reduced the statistical difference.

These findings align with Dewi et al. (2024) in UPTD Purbaratu Health Center, Tasikmalaya City, which also reported no significant association between smoking behavior and Pulmonary TB incidence (p = 0.282). Although smoking is not a direct cause of TB, it weakens lung defenses, facilitating infection by pathogens including TB bacteria. The risk worsens when smoking occurs indoors with poor ventilation, where secondhand smoke increases risks of cancer, lung disease, and cardiovascular conditions for non-smokers. Smokers are three times more likely to die from respiratory diseases than non-smokers, with the risk rising nearly fivefold for heavy smokers.[23]

Although no significant association was found in this study, smoking remains relevant in health promotion due to its harmful effects on the respiratory system. Previous studies have reported significant correlations between smoking and TB incidence. For instance, Fitrianti et al. (2022) found that smokers were 2.5 times more likely to develop Pulmonary TB than non-smokers (p = 0.013). Similarly, Sulaiman et al. (2023) reported an odds ratio (OR) of 3.181, indicating a strong association.

Interestingly, although smoking was not statistically significant in the bivariate analysis (p = 0.066), it became significant in the multivariate model (p = 0.013; OR = 7.603) after adjusting for other variables. This shift indicates the presence of a confounding effect, suggesting that the influence of smoking on pulmonary TB risk was initially masked by other correlated factors such as poor ventilation, high housing density, or contact history. Once these confounders were controlled, the independent contribution of smoking behavior to TB susceptibility became evident.

Control measures include integrating smoking cessation programs into TB services at primary health centers. These efforts should involve education on the dangers of smoking for TB patients, psychosocial support for active smokers, and the involvement of health promotion officers and TB cadres in continuous community education. Public awareness should emphasize the dangers of indoor smoking and the indirect risks of TB transmission, supporting the creation of smoke-free healthy homes.

The Most Influential Risk Factor for Pulmonary TB Incidence in the Working Area of Caile Primary Health Center, Bulukumba District

Multivariate analysis using multiple logistic regression revealed that, among the four tested variables, contact history with Pulmonary TB patients had the strongest influence on TB incidence in the working area of Caile Primary Health Center, Bulukumba District, with an odds ratio (OR) of 52.859 and a p-value of 0.001. This indicates that individuals with a history of contact with TB patients were 52.8 times more likely to develop Pulmonary TB compared to those without such contact, after controlling for other variables.

This finding is consistent with Jannah et al. (2024), who reported contact history as the most dominant factor influencing Pulmonary TB incidence, with an OR of 14.323. In this study, the high OR (52.859) for contact history indicates that most transmissions occurred through direct household interactions. Interviews and observations revealed that most case respondents lived in overcrowded houses without room separation between TB patients and other family members, reinforcing the possibility of airborne transmission in poorly ventilated, enclosed spaces.

Pulmonary TB spreads through airborne droplets expelled by active TB patients when coughing, sneezing, or talking. Household members or close contacts exposed for long periods in confined spaces are at high risk, particularly without preventive measures such as adequate ventilation or mask use. Poor housing conditions, including inadequate ventilation and high humidity, further prolong the survival of Mycobacterium tuberculosis in the air, increasing transmission risk. This suggests that while physical housing conditions are important, direct interaction with TB patients remains the primary transmission pathway.

Although contact history was the dominant factor, other variables such as housing density, inadequate ventilation, and high humidity also contributed to increased risk. Overcrowded housing facilitates intensive interactions, while poor physical housing conditions support the survival of Mycobacterium tuberculosis.

Therefore, comprehensive TB control requires not only close-contact screening but also health education on preventive behaviors, such as covering the mouth when coughing or sneezing, mask use among symptomatic family members, maintaining a clean and dry home environment, regularly opening windows for air exchange, improving ventilation, and reducing housing density.

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STRENGTHS AND LIMITATION

A key strength of this study is its comprehensive approach that simultaneously examined multiple environmental and behavioral risk factors—housing density, ventilation, humidity, contact history, and smoking status—within a high-burden TB area where such integrative analyses have been limited. The study also used both interview and direct field measurements, enhancing data reliability and contextual accuracy.

This study has several limitations that should be acknowledged. First, humidity was measured only once during field observation, which may not reflect daily or seasonal variations. Second, data on contact history and smoking behavior were collected through self-reported interviews, which may be subject to recall or reporting bias. Third, environmental measurements were taken at a single time point, limiting the ability to establish causal relationships. Despite these limitations, the study contributes important evidence on modifiable household and behavioral risk factors for pulmonary TB in a high-burden setting.

CONCLUSION AND RECOMMENDATIONS

This study concludes: 1) There is an association between housing density and the incidence of Pulmonary TB in the working area of Caile Primary Health Center, Bulukumba Regency. 2) There is an association between ventilation size and the incidence of Pulmonary TB in the working area of Caile Primary Health Center, Bulukumba Regency. 3) There is an association between humidity and the incidence of Pulmonary TB in the working area of Caile Primary Health Center, Bulukumba Regency. 4) There is an association between contact history and the incidence of Pulmonary TB in the working area of Caile Primary Health Center, Bulukumba Regency. 5) Smoking status is significantly associated with pulmonary TB after controlling for other confounding variables. 6) The most influential risk factor for pulmonary TB incidence in the working area of Caile Primary Health Center, Bulukumba Regency is contact history, with an odds ratio of 52.859.

For the Primary Health Center, it is necessary to optimize the roles of health promotion officers, sanitarians, and community health workers through regular education to the community about the importance of healthy housing, including cross ventilation and indoor humidity control. Counseling activities can be carried out through integrated health posts (Posyandu), home visits, and community forums. Health workers are also advised to actively conduct contact screening among family members of Pulmonary TB patients to enable early detection of new cases and prevent further transmission. In addition, integrating smoking cessation programs into TB services and strengthening psychosocial support for patients and families should be reinforced as part of a more comprehensive approach to controlling Pulmonary TB. For the community, it is important to increase awareness of healthy housing, improve ventilation, maintain indoor humidity at normal levels, and avoid smoking inside the house. Families with members who have symptoms or a history of Pulmonary TB are encouraged to seek medical care immediately, practice cough etiquette, wear masks, and separate sleeping arrangements during treatment to prevent transmission.

AUTHOR'S CONTRIBUTION STATEMENT

Naila Dwi Mardiyanti contributed to the conception, data collection, data analysis, and drafting of the manuscript. Andi Ruhban supervised the study design, validated the analytical methods, reviewed the results, and provided critical revisions to the final manuscript.Both authors approved the final version of the manuscript for submission.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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