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PHYSICAL HOME ENVIRONMENT AS A DETERMINANT OF PULMONARY TUBERKULOSIS RISK: A CASE-CONTROL STUDY

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ABSTRACT

Pulmonary tuberculosis (TB) remains a major global public health challenge, particularly in low- and middle-income countries. The physical home environment plays an important role in TB transmission because inadequate housing conditions facilitate the airborne spread of Mycobacterium tuberculosis. Among environmental factors, inadequate ventilation area and high occupancy density have consistently been identified as important determinants of TB transmission.

This study aimed to analyze the association between ventilation area, occupancy density, and the risk of pulmonary tuberculosis.

An observational analytic study with a case-control design was conducted at Banjarejo Primary Health Center, Madiun City, Indonesia. The study involved 46 respondents, including 23 pulmonary TB cases and 23 controls selected using a case-control approach. Data on ventilation area and occupancy density were collected through direct household observation and standardized measurements. Statistical analysis was performed using the Chi-square test, and the strength of association was estimated using Odds Ratio (OR) with 95% confidence intervals (CI)

Ventilation area was significantly associated with pulmonary TB (p = 0.038). Respondents living in houses with inadequate ventilation had a 3.556 fold higher risk of developing pulmonary TB than those living in houses with adequate ventilation (OR = 3.556; 95% CI: 1.049-12.052). Occupancy density was also significantly associated with pulmonary TB (p = 0.008).

Inadequate ventilation area and high occupancy density were significant determinants of pulmonary tuberculosis. Improving household ventilation and reducing overcrowding should be prioritized to support community-based TB prevention and reduce disease transmission, particularly in high-burden settings.

Keywords: Pulmonary tuberculosis; ventilation area; physical home environment; case-control study

INTRODUCTION

Tuberculosis (TB) remains a major global public health problem and one of the leading causes of death from infectious diseases. According to the World Health Organization (WHO), an estimated 10.8 million people developed TB and 1.25 million died from the disease worldwide in 2023 (World Health Organization, 2024). Indonesia has the second-highest TB burden globally, making TB control a national health priority.

Household environmental conditions, particularly inadequate ventilation and overcrowding, contribute to TB transmission by increasing indoor exposure to Mycobacterium tuberculosis. Both the WHO and Permenkes RI Nomor 2 Tahun 2023 emphasize adequate ventilation and healthy housing as essential measures for TB prevention.

Although previous studies have reported significant associations between ventilation, occupancy density, and pulmonary TB, evidence from the working area of Banjarejo Primary Health Center, Madiun City, remains limited. Therefore, this study aimed to analyze the association between ventilation area, occupancy density, and the risk of pulmonary tuberculosis using a case-control design.

MATERIALS AND METHODS

This study was an observational analytical study with a case–control design aimed at analyzing the association between ventilation area and occupancy density and the risk of pulmonary tuberculosis. The study was conducted in the working area of Banjarejo Primary Health Center, Madiun City, involving 46 respondents, consisting of 23 pulmonary tuberculosis cases and 23 controls selected using a case-control approach with a 1:1 ratio. The independent variables were ventilation area and occupancy density, while the dependent variable was pulmonary tuberculosis. Data on ventilation area were collected through direct household observation and standardized measurements, whereas data on pulmonary tuberculosis were obtained from the Banjarejo Primary Health Center registry. Data were analyzed using univariate analysis to describe the distribution of each variable and bivariate analysis using the Chi-square test with a 95% confidence level ($\alpha = 0.05$). The strength of the association was estimated using Odds Ratios (OR) with 95% confidence intervals (CI).

RESULTS AND DISCUSSION

Table 1 Distribution of Respondents

No	Variable	Frekuensi (f)	Persentase (%)
1.	**Age**		
	Working-age population (15-59 years)	18	39,1
	older adults (≥60 years)	28	60,9
2.	**Gender**		
	Men	26	56,5
	Women	20	43,5
3.	**Pulmonary Tuberculosis**		
	Cases	23	50,0
	Control	23	50,0

Table 1 presents the characteristics of the 46 respondents included in this study. Most respondents were older adults (≥60 years) (60.9%), while 39.1% were of working age (15-59 years). Male respondents constituted the majority (56.5%), and the numbers of pulmonary tuberculosis cases and controls were equal, with 23 respondents (50.0%) in each group.

Table 2 Association Between Ventilation Area and Pulmonary Tuberculosis

Ventilation Area	Pulmonary Tuberculosis				OR (95% CI)	P-Value
	Cases		Control			
	N	%	N	%		
Inadequate ventilation area	16	69,6	9	39,1	3,556 (1,049-12,052)	0,038
Adequate ventilation area	7	30,4	14	60,9		
Total	46	50,0	46	50,0		

Table 2 shows a significant association between household ventilation area and pulmonary tuberculosis (p = 0.038). Inadequate ventilation was more common among cases (69.6%) than controls (39.1%). Respondents living in houses with inadequate ventilation had a 3.556 fold higher risk of pulmonary tuberculosis than those with adequate ventilation (OR = 3.556; 95% CI: 1.049-12.052), indicating that inadequate household ventilation is an important risk factor for pulmonary tuberculosis.

Table 3 Association between household occupancy Density and pulmonary tuberculosis

Household Occupancy Density	Pulmonary Tuberculosis				OR (95% CI)	P-Value
	Cases		Control			
	N	%	N	%		
Non-Compliant	15	65,2	6	26,1	5,313 (1,498-18,840)	0,008
Compliant	8	34,8	17	73,9		
Total	46	50,0	46	50,0		

Table 3 shows a significant association between household occupancy density and pulmonary tuberculosis (p = 0.008). Non-compliant occupancy density was more common among cases (65.2%) than controls (26.1%). Respondents living in overcrowded houses had a 5.313-fold higher risk of pulmonary tuberculosis than those living in houses with compliant occupancy density (OR = 5.313; 95% CI: 1.498-18.840), indicating that overcrowding is an important risk factor for pulmonary tuberculosis.

DISCUSSION

Based on the results of the study conducted in the working area of Banjarejo Primary Health Center, Madiun City, involving 46 respondents, the majority were aged >60 years (28 respondents; 60.9%), male (26 respondents; 56.5%), had completed elementary school (20 respondents; 43.5%), and were housewives (13 respondents; 28.3%). The bivariate analysis showed that inadequate housing density was more common among cases (15 respondents; 65.2%) than controls (6 respondents; 26.1%), while adequate housing density was more common among controls (17 respondents; 73.9%). The Chi-Square test showed p = 0.008 and OR = 5.313 (95% CI: 1.498-18.840), indicating a significant association between housing density and tuberculosis. Respondents living in houses with inadequate density had a 5.313-fold higher risk of developing tuberculosis. According to Decree of the Minister of Health of the Republic of Indonesia No. 829/Menkes/SK/VII/1999, a bedroom should have a minimum area of 8 m² for a maximum of two occupants. This finding is consistent with Mahawati et al. (2023). Field observations showed that some houses had limited floor areas but were occupied by many family members, resulting in restricted space, closer contact, and less optimal air circulation. Housing density was measured using a roll meter to determine floor area, while the number of occupants was obtained through a questionnaire and observation checklist. The 8 case respondents with adequate housing density may have been affected by other risk factors, such as ventilation, lighting, humidity, temperature, cigarette smoke exposure, and household dust. Meanwhile, the 6 control respondents with inadequate housing density were presumed to have sufficient ventilation and lighting and better household-cleaning practices.

Regarding ventilation area, inadequate ventilation was more common among cases (16 respondents; 69.6%) than controls (9 respondents; 39.1%), while adequate ventilation was more common among controls (14 respondents; 60.9%). The Chi-Square test showed p = 0.038 and OR = 3.556 (95% CI: 1.049-12.052), indicating a significant association between ventilation area and tuberculosis. Respondents living in houses with inadequate ventilation had a 3.556-fold higher risk of developing tuberculosis. According to Minister of Health Regulation of the Republic of Indonesia No. 2 of 2023, household ventilation should support adequate air exchange, with a ventilation area of approximately 10% of the floor area. This finding is consistent with Mahawati et al. (2023) and Razak et al. (2025). Field observations showed that inadequate ventilation among cases was mainly caused by small openings, furniture blocking ventilation, permanent glass installations, or windows that were rarely opened, resulting in poor air circulation. Ventilation area was measured using a roll meter, while housing conditions were assessed using an observation checklist. Respondent characteristics were obtained through questionnaires, while tuberculosis status was obtained from Banjarejo Primary Health Center records. Therefore, adequate ventilation should be supported by regularly opening windows and ventilation openings to optimize air circulation and natural lighting and minimize the risk of tuberculosis transmission.

CONCLUSION

This study demonstrated that inadequate ventilation area was significantly associated with pulmonary tuberculosis. Houses with inadequate ventilation had a higher risk of pulmonary tuberculosis than those with adequate ventilation, indicating that ventilation is an important environmental determinant of TB transmission. Therefore, improving household ventilation in accordance with environmental health standards should be prioritized as part of community-based tuberculosis prevention. These findings provide evidence to support environmental health interventions and strengthen tuberculosis control policies, particularly in high-burden settings.

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