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Effectiveness of Improving Home Environment as A Measure to Prevent the Transmission of Pulmonary Tuberculosis in Badung Regency: A Quasi-Experimental Study

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Abstract
Pulmonary tuberculosis (TB) remains a public health problem in Indonesia, including in Badung Regency, Bali. A physical home environment that does not meet health standards, such as poor ventilation, insufficient lighting, high humidity, and inappropriate room temperatures, can increase the risk of TB transmission. The objective of this study was to improve the home environmental quality, including room temperature, lighting, humidity, and ventilation rates, before and after environmental improvement interventions in the homes of pulmonary TB patients. The study employed a quasi-experimental design with a pre-posttest approach. The study sample consisted of 10 households of pulmonary TB patients located within the service areas of 10 community health centers (Puskesmas) in Badung Regency, Bali. The instrument used a digital thermo-hygrometer to measure temperature and humidity; a lux meter to measure lighting; and an anemometer to measure ventilation rate. The analysis used the McNemar test at a 95% significance level. The results show that before the intervention, the majority of homes did not meet the criteria for room temperature (70%), lighting (70%), humidity (90%), and ventilation rate (80%). After intervention, the proportion of homes that met the criteria increased to 90% for room temperature and lighting, 80% for humidity, and 80% for ventilation rate. The McNemar test showed significant differences in room temperature (p=0.031), lighting (p=0.031), humidity (p=0.016), and ventilation rate (p=0.031). In conclusion, enhancing natural ventilation, natural lighting, and humidity control in homes where people with pulmonary TB live improves the physical environment.

Keywords: Environmental Quality, Lighting, Temperature And Humidity, Tuberculosis, Ventilation Rate

1. Introduction

Tuberculosis (TB) is an infectious disease that remains a global health problem. Data from the World Health Organization (WHO) show that in 2018 there were approximately 10 million cases of TB worldwide, with Indonesia ranking among the eight countries with the highest number of cases, along with India, China, the Philippines, Pakistan, Nigeria, Bangladesh, and South Africa (World Health Organization, 2019). Even before the

COVID-19 pandemic, TB surpassed HIV/AIDS as the leading cause of death (Suryanti & Ahmed, 2025). According to data from the Ministry of Health of the Republic of Indonesia, the number of TB cases detected in 2019 reached 543,874, while in 2018 there were 566,623 cases (Ministry of Health of Indonesia, 2020). In Bali Province, the number of TB cases in 2020 reached 2,873, with Badung Regency being one of the regions with the highest number of cases at 400 (Dinas Kesehatan Provinsi Bali (Bali Department of Health), 2021). The transmission of pulmonary TB is influenced by interactions among the pathogen, the host, and the environment. The physical environment of a home plays a crucial role in determining the survival of *Mycobacterium tuberculosis* (Cut Fidha Balkis et al., 2026; Ehrt & Schnappinger, 2009; Lili Amaliah et al., 2022). Homes with poor ventilation, low lighting, inappropriate temperatures, and high humidity can create conditions that support the long-term survival of TB bacteria (Fahdhienie et al., 2024; Marni et al., 2024; Meliyanti, 2026).

A study showed that poor home lighting increases the risk of pulmonary TB by 6.67 times compared to homes with good lighting. A study also showed that housing density, ventilation, lighting, and humidity are significantly associated with the incidence of pulmonary TB (Sahadewa et al., 2019). A previous study conducted by (Suyasa et al., 2024) in Badung Regency showed that the knowledge and behaviors of pulmonary TB patients remain low. A total of 90.3% of respondents had insufficient knowledge, and 68.2% exhibited inadequate TB prevention behaviors. The analysis results indicated a significant association between knowledge and behavior and the incidence of pulmonary TB (p=0.001). Previously, research about the environment in TB patients was conducted. In (Metri, 2025), a study of the related physical environment with TB prevention was performed, where the homelighhting, home cleanliness was identified as the most influential factors in preventing pulmonary TB transmission. Besides, research about the correlation between clean and healthy living behavior and the condition of the home environment was conducted. It shows that TB patients have a moderate level of clean and healthy living behavior (39.2%), and they live in unhealthy homes (57.9%) (As et al., 2025). A study about counseling has also been conducted to improve public knowledge and behavior in preventing TB transmission. It revealed that the counseling has increased the participants' knowledge by 37.7% with positive behavioral changes (Sirait et al., 2025). However, these studies analyzed only the correlation between the factors, and there is a gap in the implementation or intervention to change the home environment condition. A home environment that does not meet health standards allows TB bacteria to survive longer in the air, thereby increasing the risk of transmission to other family members. Therefore, interventions aimed at improving the quality of the home environment are needed as part of family-based efforts to prevent TB transmission.

This study aims to measure changes in room temperature, lighting, humidity, and ventilation rates before and after improvements were made to the home environment of pulmonary TB patients in Badung Regency.

2. Method

This study employed a quantitative method with a quasi-experimental pre-posttest control group design. An experimental study is defined as the most comprehensive quantitative research approach, meaning it meets all requirements for testing cause-and-effect relationships (Sahir, 2021). The study population consists of all subjects or objects with specific characteristics under investigation. This study population consists of all households with pulmonary TB patients located within the service areas of the 10 Community Health Centers (*Puskesma*s) in Badung Regency, Bali. The study sample comprised 10 households with pulmonary TB patients, selected through purposive sampling based on predetermined inclusion criteria. The intervention involved improving natural ventilation in the homes, optimizing natural lighting, controlling indoor humidity, and providing education on maintaining a healthy environment. The study variables included room temperature (°C) with a quality standard of 18–30°C, lighting (lux) with a minimum quality standard of 60 lux, humidity (%) with a quality standard of 40–60%, and ventilation rate (m/second) with a standard requirement of 0.15–0.25 m/second.

Data collection is a research activity aimed at gathering data. Before conducting data collection, it is necessary to consider the data collection instruments to strengthen the research results. These data collection instruments may include questionnaires, observations, interviews, or a combination of all three. The research variables, room temperature and humidity, were measured using a digital thermohygrometer in the morning and afternoon in the main room; room temperature was measured in degrees Celsius (°C) and humidity in percent (%). The lighting

variable was measured using a lux meter during the day (10:00 a.m.–2:00 p.m.) in lux, while the ventilation rate was measured using an anemometer in m/s. The data were analyzed univariately to describe the characteristics of the respondents and the quality of the home environment. Bivariate analysis used the McNemar test to determine differences in environmental quality before and after the intervention at a 95% confidence level ($\alpha = 0.05$).

3. Results

3.1 Characteristics of Respondents

Characteristics of the study respondents are categorized by gender, age, education, occupation, and income. The youngest respondent was 15 years old, and the oldest was 88 years old, with an average age of 50.6 ± 23.99 years; the average number of household members was 4.3 ± 1.57. The distribution of respondents by gender, education, occupation, and income is presented in Table 1.

Table 1: Characteristics of respondents

Characteristics	Frequency (n)	Percentage (%)
Gender		
Male	8	80
Female	2	20
Total	10	100
Education		
Elementary School	4	40
Junior High School	4	40
Senior High School	2	20
Total	10	100
Occupation		
Unemployed	3	30
Farmer	2	20
Laborer	3	30
Entrepreneur	2	20
Total	10	100
Monthly income		
Rp1.5–2 million	5	50
>Rp2–2.5 million	4	40
>Rp2.5–3 millioin	1	10
Total	10	100

Based on Table 1, the majority of respondents were male (80%). In terms of educational attainment, elementary and junior high school graduates each accounted for 40% of the respondents, while high school graduates accounted for 20%. Meanwhile, in terms of employment, the majority of respondents worked as laborers (30%) or were unemployed (30%). Family income was mostly in the range of Rp1.5–2 million per month (50%).

3.2 Environment Quality

Environmental quality was assessed through observations conducted before and after the intervention on air quality, using the parameters of room temperature, lighting, humidity, and ventilation rate. The results of the environmental quality assessment are shown in Table 2.

Table 2: Environmental quality in the respondents' home before and after the intervention

Variable	n (%) Before Intervention	n (%) After Intervention
Room temperature		
Unqualified	7 (70.0)	1 (10.0)
Qualified	3 (30.0)	9 (90.0)
Lighting		
Unqualified	7 (70.0)	1 (10.0)
Qualified	3 (30.0)	9 (90.0)
Humidity		
Unqualified	9 (90.0)	2 (20.0)
Qualified	1 (10.0)	8 (80.0)
Ventilation rate		
Unqualified	8 (80.0)	2 (20.0)
Qualified	2 (20.0)	8 (80.0)

Table 2 shows that before environmental improvements were made, most of the respondents' homes had environmental conditions that did not meet health standards, including indoor or room temperature (70.0%), lighting (70.0%), humidity (90.0%), and ventilation rate (80.0%). Following interventions involving improvements to natural ventilation, increased natural lighting, and humidity control, there was an increase in the proportion of homes meeting health standards. The proportion of homes with temperature and lighting that met the standards rose to 90.0%, while those with humidity and ventilation rates that met the standards rose to 80.0% each.

3. Statistical Analysis on Environmental Quality

An analysis of differences in environmental quality before and after the intervention was conducted using the McNemar test. Table 3 shows the results of the statistical test.

Table 3: McNemar test results on environmental quality changes

Variable	N (%) Unqualified Before Intervention	N (%) Qualified After Intervention	p-value
Room temperature	7 (70.0)	9 (90.0)	0.031
Lighting	7 (70.0)	9 (90.0)	0.031
Humidity	9 (90.0)	8 (80.0)	0.016
Ventilation rate	8 (90.0)	8 (80.0)	0.031

Based on the results of the analysis using the McNemar test on Table 3, there are significant changes in all indoor environmental quality parameters following the intervention. Significant changes are found in room temperature (p=0.031), lighting (p=0.031), humidity (p=0.016), and ventilation rate (p=0.031). These results indicate that improvements in the home environment are effective in enhancing the physical quality of the homes of patients with pulmonary TB.

4. Discussion

The study results show that the majority of respondents were male (80%), with an average age of 50.6 ± 23.99 years. These findings are consistent with the epidemiological profile of tuberculosis (TB) in Indonesia and worldwide, which indicates that men are at higher risk of developing TB than women. According to a WHO report,

approximately 56% of global TB cases occur in adult men. The high proportion of men in this study may be attributed to behavioral factors, high occupational mobility, exposure to occupational risk factors, smoking habits, and delays in seeking healthcare (Jiang et al., 2026; World Health Organization, 2025).

Most respondents had a low level of education, with 40% being elementary school graduates and 40% junior high school graduates. Education is one of the social determinants of health that influences an individual's ability to understand health information, adopt clean and healthy living behaviors, and take steps to prevent disease. Previous research has shown that a low level of education is associated with limited knowledge about TB, delayed diagnosis, and low adherence to behaviors that prevent the transmission of TB (Suyasa et al., 2024). Regarding occupation, most respondents were laborers (30%) or unemployed (30%). This indicates that the majority of respondents came from lower-middle socioeconomic groups. Low socioeconomic status is often associated with poor housing quality, high housing density, and limited ability to improve the home environment. According to a study conducted by (Sulidah et al., 2024), low socioeconomic status is a factor contributing to an increased risk of TB because it is associated with an unhealthy living environment.

The study results show that before the intervention, the majority of respondents' homes had physical environmental conditions that did not meet health standards. A total of 70% of homes had indoor temperatures that did not meet standards, 70% had inadequate lighting, 90% had high humidity, and 80% had ventilation rates that did not meet health standards. These conditions indicate that the homes of most people with pulmonary TB still contain environmental factors that could potentially increase the risk of disease transmission. A closed-off home environment with insufficient sunlight and inadequate ventilation can allow *Mycobacterium tuberculosis* bacteria to survive longer in the air and increase the likelihood of transmission to other family members (World Health Organization, 2025).

Following interventions such as improvements to natural ventilation, increased natural lighting, and humidity control, there is a significant improvement in all parameters of indoor environmental quality. The percentage of homes meeting indoor temperature standards increased from 30% to 90%, lighting improved from 30% to 90%, humidity levels rose from 10% to 80%, and ventilation rates increased from 20% to 80%. These improvements indicate that simple environmental interventions in the homes of people with TB can have a tangible impact on the physical quality of the home environment. The results of this study align with research (Nada Zahra et al., 2025) showing that home ventilation, lighting, and humidity are key factors influencing the incidence of pulmonary TB in the community. Improving home environmental conditions can reduce exposure to infectious droplets containing *Mycobacterium tuberculosis*, thereby contributing to efforts to prevent disease transmission.

The study results show that improving the quality of the home environment can significantly enhance the physical conditions of the homes of people with pulmonary TB. Before the intervention, most homes had inadequate ventilation, poor lighting, high humidity, and suboptimal room temperatures. The increase in appropriate room temperatures following the intervention indicates that improvements in ventilation and lighting were able to enhance indoor air circulation. Good air circulation helps reduce the concentration of droplets containing *Mycobacterium tuberculosis*, thereby lowering the risk of transmission. Research findings indicate that interventions to improve the home environment can significantly improve the physical conditions of people with pulmonary TB. Improvements in ventilation and natural lighting have been shown to improve indoor air quality, thereby potentially reducing the risk of TB transmission. These results are consistent with studies showing that inadequate ventilation increases the risk of pulmonary TB due to limited air circulation and increased concentrations of droplets containing *Mycobacterium tuberculosis* (Nurjannah & Yuantari, 2024).

According to the Ministry of Health of the Republic of Indonesia, the ideal indoor temperature ranges from 18–30°C. Temperatures that are too high or too low can affect indoor air quality and contribute to an increased risk of environment-related diseases (Ministry of Health of Indonesia, 2024). The results of this study indicate that improving the physical environment of homes can be an effective strategy for creating healthier temperature conditions for residents.

Lighting is one of the environmental factors that has a significant impact on TB transmission. In this study, the proportion of homes with adequate lighting increased from 30% to 90% following the intervention. The results of the McNemar test showed a significant change (p=0.031). The improvement in lighting was achieved through the optimization of window openings, the reduction of barriers to sunlight, and the utilization of natural lighting. Sunlight contains ultraviolet rays, which are known to damage the DNA structure of *Mycobacterium tuberculosis*, thereby reducing the bacteria's ability to survive in the environment. These findings are consistent with a study (Kencana, 2024) that concluded that homes with inadequate lighting have a higher risk of pulmonary TB compared to homes with good lighting. Another study conducted by (Fitriani, 2020) also showed that the quality of home lighting has a significant association with the incidence of pulmonary TB. Therefore, increasing access to sunlight inside the home is a simple yet effective environmental intervention to support TB prevention. Improvements in natural lighting have also shown significant results. Sunlight contains ultraviolet radiation that can inhibit or even kill TB bacteria in the environment. These findings align with a study by (Sahadewa et al., 2019), which states that home lighting is associated with the incidence of pulmonary TB. The increase in natural lighting that occurred following the intervention also supports TB prevention efforts. Sunlight, particularly ultraviolet rays, is known to inhibit the growth of TB bacteria in the home environment. Several studies indicate that homes with poor lighting have a higher risk of TB cases compared to homes with lighting that meets health standards.

Humidity was the parameter that showed the greatest change in this study. Before the intervention, 90% of homes had humidity levels that did not meet health standards. After the intervention, the proportion of homes meeting the standards increased to 80%. The analysis results indicate a statistically significant change (p=0.016). High humidity can increase bacteria's ability to survive longer in the home environment. Additionally, high humidity is often associated with the growth of mold, other microorganisms, and a decline in indoor air quality. These conditions can worsen the respiratory health of household occupants.

Research indicates that household humidity is one of the environmental factors associated with the incidence of pulmonary TB. By improving ventilation and natural lighting, indoor humidity can be controlled, thereby creating an environment less conducive to the survival of *Mycobacterium tuberculosis*(Nurjannah & Yuantari, 2024) . The decrease in indoor humidity following the intervention indicates that improved ventilation can enhance air exchange, thereby reducing indoor water vapor levels. High humidity is known to support the survival of *Mycobacterium tuberculosis* for longer periods. The significant decrease in indoor humidity observed in this study indicates that ventilation modifications can improve air exchange and reduce water vapor levels inside the home. Humid conditions are known to provide an environment that supports the survival of TB bacteria for a longer period of time.

Ventilation rate is a critical factor in controlling TB transmission because it is directly related to the process of air exchange. Research findings show that the proportion of homes with adequate ventilation increased from 20% to 80% following the intervention. The McNemar test revealed a significant change (p=0.031). Good ventilation reduces the concentration of infectious droplets in the air through dilution and the expulsion of contaminated air to the outside environment. The WHO emphasizes that ventilation is one of the key strategies in environment-based TB transmission prevention, particularly in homes with family members who have active TB (World Health Organization, 2025). These findings are supported by a meta-analysis by (Jannah et al., 2023), which showed that inadequate home ventilation significantly increases the risk of TB cases. Similar results were also reported by (Nada Zahra et al., 2025), who found that homes with poor ventilation are more likely to experience TB cases compared to homes with adequate ventilation. Increased ventilation rates also indicate that modifications to natural ventilation effectively improve air exchange between the interior and exterior of the home. These findings are supported by a study by (Perdana & Putra, 2018), which states that home ventilation is a major risk factor for pulmonary TB.

The results of this study indicate that interventions to improve the home environment are an effective strategy for improving the quality of the physical environment in the homes of people with TB. TB control programs have traditionally focused primarily on case detection and treatment. However, controlling environmental factors needs to be an integral part of TB elimination strategies. Interventions such as improving natural ventilation, optimizing lighting, and controlling humidity are relatively easy to implement, low-cost, and can be sustained by the

community. Therefore, community health centers and local governments need to develop support programs for families of TB patients that focus not only on treatment adherence but also on home environment improvements as a means of preventing transmission at the household level.

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