

RESEARCH ARTICLE

Active Tuberculosis Screening, Preventive Behavior, and Environmental Risk Assessment in Islamic Boarding Schools in Central Java, Indonesia

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ABSTRACT

Introduction: Islamic boarding schools are congregate settings susceptible to the spread of infectious diseases, including tuberculosis (TB), because students live in close proximity. This study aimed to assess preventive behaviours and environmental conditions that may influence the potential for TB transmission in Islamic boarding schools in Banyumas Regency, Central Java, Indonesia.

Methods: This quantitative cross-sectional survey included 439 students selected on the basis of TB-related symptoms, contact history, or a combination of these criteria. All 439 students underwent initial screening, and those meeting the prespecified criteria were referred for Xpert MTB/RIF examination. Environmental measurements included temperature, humidity, lighting, occupancy density, ventilation area, and cleanliness.

Results: Of the 439 students examined, one (0.2%) tested positive for TB using Xpert MTB/RIF (TCM), while 438 (99.8%) tested negative. Knowledge was significantly associated with prevention behaviour ($p = 0.023$). In addition, 11.4% of students reported that they did not practise handwashing after travelling or participating in outdoor activities. Environmental conditions were suboptimal. The ventilation area ranged from 9.93% in Boarding School B to 13.33% in Boarding School A, compared with the national standard of 10%–20%. Occupancy density did not meet the applicable national standard. Mean lighting met the standard in both boarding schools, while room cleanliness was inadequate and relative humidity was high.

Conclusion: Active TB case finding identified one positive case and highlighted the need to integrate behavioural and environmental prevention measures in Islamic boarding schools.

Keywords: Active Case Finding; Transmission; Tuberculosis; Islamic Boarding Schools

INTRODUCTION

Tuberculosis (TB) is one of the world's leading causes of infectious disease and death. In 2023, 10.8 million people were diagnosed with TB, with children accounting for 12% of cases. TB is also among the top ten causes of death in children globally (1,2). Indonesia has the world's second-highest TB burden after India, and 867,480 TB cases were notified nationally in 2025 (3). The TB mortality rate in Indonesia remains relatively high; in 2018, it was 35 deaths per 100,000 population. Moreover, between 2015 and 2023, the incidence rate increased by 19%, while the mortality rate increased by 26%. These findings indicate that TB remains a substantial disease burden in Indonesia (4). Crowded living conditions and limited access to healthcare services increase the risk of TB, especially in institutional settings where people live in close proximity for extended periods (5).

In 2023, Banyumas Regency recorded a TB incidence of 418 per 100,000 population and 7,157 notified TB cases, a 7% increase from 6,683 cases in the previous year (6). The high incidence and rising case burden present challenges to TB control. Intensified case-finding and improved treatment are needed to support the national TB elimination target for 2030.

Environmental and behavioural factors play a crucial role in TB transmission. *Mycobacterium tuberculosis* can survive in poorly ventilated, humid, and crowded indoor environments, increasing the likelihood of airborne spread. The physical environment plays a significant role in the transmission of tuberculosis. A meta-analysis showed that household crowding and physical environmental conditions can increase TB transmission (7). Another study demonstrated an association between environmental health conditions and TB cases (8). Islamic boarding schools are distinctive learning environments in which students share dormitories, study areas, and daily routines. Combined with poor ventilation and limited environmental health controls, these conditions may increase the risk of airborne infections, including TB (9–13).

High-risk settings for TB transmission include dormitories prisons military barracks schools and public transport (14–16). Students with TB often have delayed detection overcrowded classrooms and repeated exposure to infectious contacts (17,18). In densely populated or high-occupancy settings delays in identifying the index case poor cough etiquette and inadequate infection-prevention practices can accelerate TB transmission (17,19). The spread of tuberculosis in Islamic boarding schools is significantly influenced by overcrowding and inadequate air circulation. Furthermore the adoption of clean and healthy behaviours is also found to play a pivotal role in the propagation of tuberculosis within such educational (20,21). Studies in Indonesia and other ASEAN countries show that students' knowledge, attitudes, perceptions and behaviours are important for TB prevention and early detection (22–24). Many adolescents have misconceptions about TB transmission, treatment, and reinfection, which may undermine TB control programmes. Behavioural factors such as mask use, cough etiquette, and personal hygiene may also influence TB transmission in schools (22).

Given these concerns, it is essential to strengthen active case finding (ACF) and contact investigation in Islamic boarding schools to identify undiagnosed TB cases, interrupt transmission and prevent outbreaks. ACF programmes in high-risk populations increasingly incorporate rapid molecular diagnostic tests, although programme scale, testing coverage, and implementation quality remain important challenges (25). It is therefore crucial to understand the interplay between students' knowledge, preventive behaviours, and environmental conditions to design comprehensive TB control interventions in Islamic boarding schools.

Despite the recognised vulnerability of Islamic boarding schools to TB transmission, active case finding (ACF) has not been routinely implemented in these institutions, reflecting a service-delivery gap in TB control programmes. In parallel, an evidence gap persists: few studies have jointly examined diagnostic yield, students' preventive behaviours and environmental conditions within a single pesantren-based assessment. Addressing both gaps requires a context-specific, integrated approach that combines active case finding with an assessment of the behavioural and environmental conditions surrounding TB transmission potential in this setting.

This study aimed to identify gaps in TB detection while assessing students' preventive behaviours and evaluating environmental conditions that may influence the potential for TB transmission in Islamic boarding schools. By integrating active case finding with behavioural and environmental assessment, the study sought to provide context-specific evidence to inform targeted TB prevention strategies in these settings.

METHODS

Study Design and Setting

This analytical cross-sectional study was conducted at two Islamic boarding schools in Banyumas Regency, Central Java: Islamic Boarding School A in Cilongok District and Islamic Boarding School B in Tambak District (Figure 2). The selected schools had previously reported TB cases and therefore required active case finding. Both are residential educational institutions in which students may be exposed to TB transmission.

Study Population and Sampling

The study population consisted of 1,916 students from the two selected Islamic boarding schools. Initial screening was conducted using a Google Forms questionnaire assessing TB-related symptoms, contact history, medical history, and relevant risk factors. The 10-item screening tool included: (1) cough persisting for approximately two weeks; (2) haemoptysis; (3) intermittent fever lasting approximately one month; (4) unexplained night sweats; (5) unexplained weight loss; (6) enlarged lymph nodes, particularly a lump in the neck region; (7) shortness of breath and chest pain; (8) a history of previous treatment with pulmonary medications; (9) living with or having close contact with a household member who had previously been

diagnosed with TB or reported to have “lung spots”; and (10) a history of asthma, diabetes mellitus, chronic obstructive pulmonary disease (COPD), or HIV/AIDS.

Eligibility for further diagnostic evaluation using Xpert MTB/RIF was defined as meeting either of the following criteria:

Contact criterion: A documented history of close contact with a patient with TB (n = 30).

Symptom criterion: A positive response to at least three of the seven TB-related symptom items assessed in the screening tool (cough persisting for approximately two weeks, haemoptysis, intermittent fever lasting approximately one month, unexplained night sweats, unexplained weight loss, enlarged lymph nodes, or shortness of breath/chest pain).

Either a history of contact alone or the presence of at least three symptoms was sufficient for diagnostic referral. Contact history was operationally defined as living in the same dormitory or household as, or sharing close indoor space with a confirmed pulmonary TB patient. Based on this eligibility rule, 439 of 1,916 students (22.9%) met the criteria and were referred for Xpert MTB/RIF testing (26)

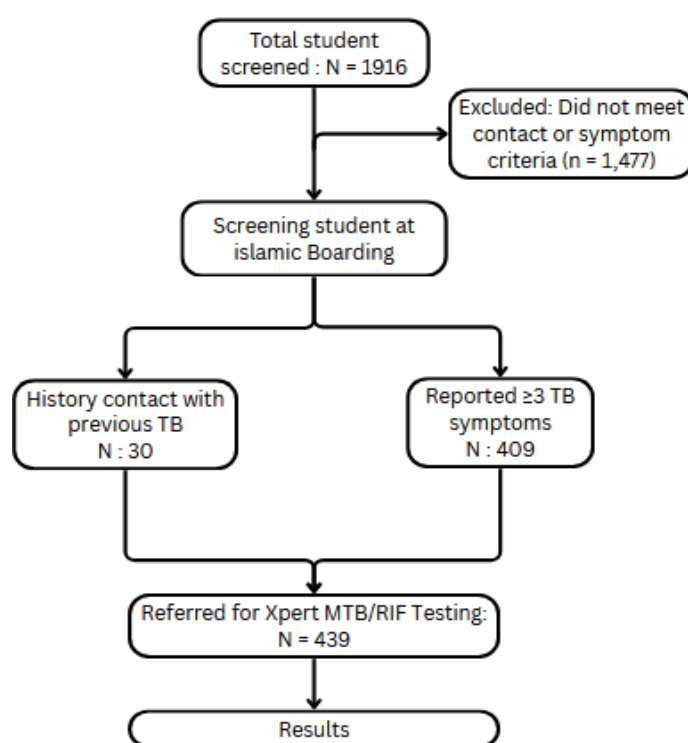


Figure 1. Flow diagram of Xpert MTB/RIF screening

Data Collection

Data collection was conducted from May to September 2025 and included three components: clinical examination, assessment of knowledge and behaviour, and assessment of environmental conditions.

Clinical Screening

TB diagnosis was based on the Xpert MTB/RIF (TCM) test, which was performed by trained personnel. The procedure was as follows: (1) students were prepared in a designated room and provided with a sputum collection container labelled with a unique identifier; (2) students were instructed in proper sputum production techniques, including taking a deep breath, holding it briefly, and coughing forcefully to expel mucus from the lower respiratory tract rather than saliva; (3) students collected 3–5 mL of sputum in a designated private room using the labelled container; (4) specimens were checked for adequate volume and quality before transport to the hospital laboratory for Xpert MTB/RIF analysis; and (5) laboratory staff from the community health centre assisted throughout data collection. Sputum was collected as a single spot specimen on site during the screening visit. A total of 439 eligible students underwent Xpert MTB/RIF testing in accordance with the screening decision rule, which required either a history of TB contact or a positive response to at least three of the seven TB-related symptom items assessed in the screening tool. All 439 sputum specimens met the stipulated quality requirements and yielded valid diagnostic results; no invalid or indeterminate results were recorded.

Knowledge and Behaviour Measurement

Structured questionnaires and interviews were used to assess students' knowledge of and behaviour related to TB. The knowledge assessment covered the definition of the disease, its symptoms, modes of transmission, cough etiquette, proper handwashing techniques, and use of personal protective equipment. Before the knowledge and behaviour assessment, the 10 enumerators who also served as data collectors were trained to conduct the interviews. The questionnaire was developed

and pilot-tested before use and had established validity and reliability. It consisted of 12 questions, including two reverse-worded items (items 6 and 7). For these two items, the response reflecting correct TB knowledge was scored 1 and the other response was scored 0; for the remaining items, correct responses were scored 1 and incorrect responses were scored 0. As the data were not normally distributed, a median score of 10 was used as the threshold for classifying knowledge as good or poor. Validity testing showed that all item *r*-values exceeded the critical *r*-value of 0.361. Reliability testing yielded a Cronbach's alpha coefficient of 0.76.

Environmental Measurement

A two-stage sampling strategy was used for room selection. First, two Islamic boarding schools in Banyumas Regency—one modern located in Cilongok district and one traditional located in Tambak District—were purposively selected to represent contrasting structural and managerial models. Second, dormitory rooms within each school were selected using stratified simple random sampling to ensure representation across building locations, floor levels, cardinal orientations, corner positions, and occupants' educational levels. A total of 20 observation points were evaluated (10 in the modern school and 10 in the traditional school), comprising five male and five female student dormitory rooms per institution.

Environmental parameters, including temperature, relative humidity, light intensity, ventilation area, and occupancy density, were assessed on 27 August 2025 at the modern Islamic boarding school and on 9 September 2025 at the traditional Islamic boarding school. Measurements were taken during active daytime hours (08:00–11:00 and 13:00–16:00) under typical occupied-room conditions with resident students present. Windows, doors, and ventilation openings were assessed in their naturally occurring state, as routinely operated by occupants during daily activities. At each observation point, three readings were recorded over a 15–20-minute stabilisation period at breathing-zone height (1.0–1.5 metres above the floor), and the mean value was calculated for statistical analysis.

The measuring instruments were calibrated and standardised by the Occupational Safety and Health Laboratory at Universitas Jenderal Soedirman. Temperature and relative humidity were measured using a digital thermohygrometer, whereas illuminance (natural lighting) was measured using a lux meter. Occupancy density was calculated as the ratio of total room floor area (m²) to the number of regular occupants. Environmental benchmarks were based on Indonesian Ministry of Health Regulation No. 2 of 2023. Room cleanliness was operationally defined according to the presence of potential contamination sources, including household waste, dust, dirt, and disease vectors; rooms with no contamination sources were categorised as clean, whereas those with one or more sources were categorised as unclean.

Unrecorded parameters included continuous 24-hour longitudinal logging, real-time air exchange rates (air changes per hour [ACH]), and outdoor ambient meteorological fluctuations outside the testing windows; these were not prospectively recorded during this cross-sectional assessment.

Variables and Data Analysis

This study examined three domains: knowledge, behaviour, and environmental conditions. Knowledge and behaviour scores were classified as good or poor using a median split because the data were not normally distributed. Environmental indicators were assessed against standards established by the World Health Organization (WHO) and the Ministry of Health of the Republic of Indonesia for healthy housing. Data were analysed descriptively using frequencies, and a chi-square test was used to examine the association between students' knowledge and TB prevention practices.

Ethical Considerations

This study received ethical approval from the Ethics Committee of the Faculty of Health Sciences, Jenderal Soedirman University (Approval No. 154/EC/KEPK/V/2025). Written informed consent was obtained from all participants, and parental or school consent was secured for participants younger than 18 years. All data were stored securely, and confidentiality was maintained. Collaboration with the local primary health centre (*Puskesmas*), the District Health Office, and the Army Hospital (RS DKT) was established to ensure biosafety throughout the study and the proper handling of TCM samples.

Data Availability Statement

The datasets generated and/or analyzed during the current study are not publicly available due to ethical considerations and the need to protect participants' privacy and confidentiality. However, the data are available from the corresponding author upon reasonable request, subject to applicable ethical and institutional requirements. Table 1. PCC Framework: Inclusion and Exclusion Criteria

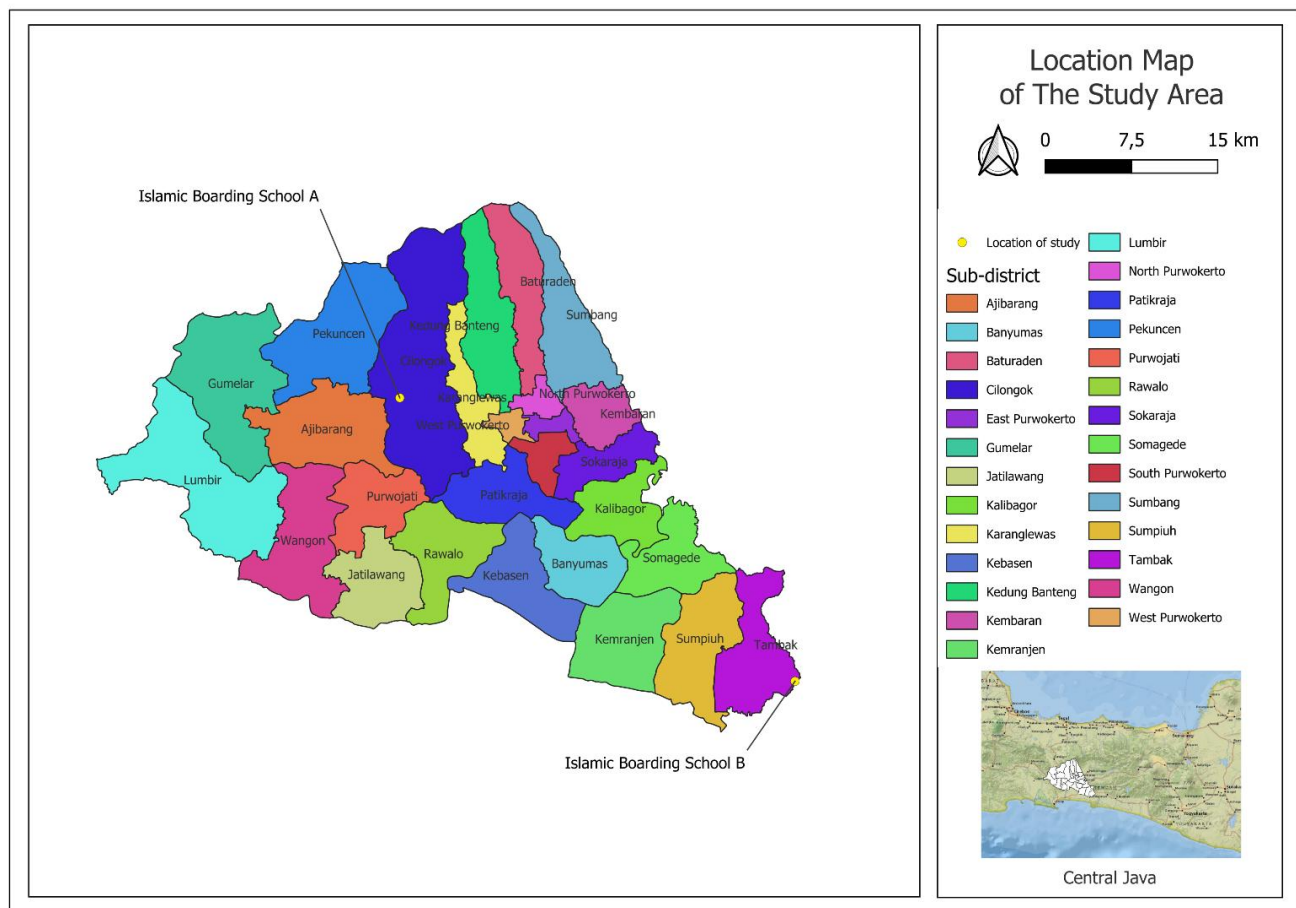


Figure 2. Location of the study sites

RESULTS

Characteristics of Participants

A total of 1,916 students were screened using a questionnaire to ascertain their TB contact history and symptoms. Students who met the symptom criterion, the contact-history criterion, or both were considered eligible and were asked to submit a sputum sample for TB testing. Of the 1,916 students who completed the questionnaire, 439 (22.9%) were eligible and underwent TCM testing.

Table 1. Characteristics of Students Undergoing TCM Examination in Banyumas Regency, Central Java, Indonesia

Variables	n	Frequency
		%
Age		
<15 years	163	37.1
≥15 years	276	62.8
Gender		
Male	199	45.3
Female	240	54.7
Education		
Elementary School	0	0
Junior High School	427	97.2
Senior High School	12	2.8
Total	439	100.0

As shown in Table 1, 276 students (62.8%) were aged ≥15 years and 163 (37.1%) were aged <15 years. The sample comprised 199 male students (45.3%) and 240 female students (54.7%). Most students were in junior high school (427; 97.2%), while 12 (2.8%) were in senior high school; none were in elementary school.

Xpert MTB/RIF (TCM) Results

Xpert MTB/RIF testing was conducted after student screening based on reported symptoms and documented close contact with individuals diagnosed with TB. The results are presented in Table 2.

Table 2. Xpert MTB/RIF Examination Results in Islamic Boarding Schools in Banyumas Regency, Central Java

TCM result	n	%
Positive	1	0.2
Negative	438	99.8
Total	439	100.0

Among the 439 students who underwent Xpert MTB/RIF testing, 438 (99.8%) had negative results and one (0.2%) had a positive result. The positive case was a 13-year-old male who reported cough symptoms (Table 2).

Knowledge of Respondents Regarding TB Prevention

As shown in Table 3, 231 students (52.6%) had good knowledge and 208 (47.4%) had poor knowledge. These findings indicate variation in students' understanding of TB and identify areas for health education within boarding schools.

Table 3. Distribution of Students' Knowledge of Tuberculosis in Islamic Boarding Schools in Banyumas Regency, Central Java

Knowledge	n	%
Poor	208	47.4
Good	231	52.6
Total	439	100.0

Table 4 summarises responses to the individual knowledge items, including knowledge of TB definitions, aetiology, transmission, hygiene practices, and cough etiquette.

Table 4. Distribution of Knowledge-Item Responses Among Students in Islamic Boarding Schools

Item / Statement	Corr. n	Corr. %	Inc. n	Inc. %	Total n	Total %
1. Tuberculosis is a disease that affects the lungs as a result of bacterial infection	411	93.6	28	6.4	439	100.0
2. Tuberculosis is caused by <i>Mycobacterium tuberculosis</i>	415	94.5	24	5.5	439	100.0
3. One of the symptoms experienced by patients with tuberculosis is coughing up blood	361	82.2	78	17.8	439	100.0
4. Night sweats are also a symptom of tuberculosis	373	85.0	66	15.0	439	100.0
5. Transmission of tuberculosis infection can occur through the sputum of infected individuals	393	89.5	46	10.5	439	100.0
6. Tuberculosis is a hereditary disease passed from parents to their children *	131	29.8	308	70.2	439	100.0
7. People who have had tuberculosis cannot develop tuberculosis again after they recover *	92	21.0	347	79.0	439	100.0
8. To prevent the transmission of tuberculosis, individuals are advised to receive BCG immunisation during early childhood	360	82.0	79	18.0	439	100.0
9. Washing hands with running water and soap is part of clean and healthy living behaviour.	426	97.0	13	3.0	439	100.0
10. Covering the mouth and nose when coughing or sneezing is one of the ways to prevent the transmission of tuberculosis.	420	95.7	19	4.3	439	100.0
11. Tuberculosis treatment is carried out for six consecutive months	341	77.7	98	22.3	439	100.0
12. To detect whether a person is infected with tuberculosis, sputum examination is performed	398	90.7	41	9.3	439	100.0

Table 4 uses "Correct" and "Incorrect" response categories. Items 6 and 7 are reverse-worded; for these two items, an "Incorrect" response to the statement reflects correct TB knowledge. Most respondents correctly recognised that TB is not hereditary (70.2%; item 6) and that reinfection can occur after recovery (79.0%; item 7). However, 29.8% believed that TB could be inherited, 21.0% believed that reinfection was not possible, and 22.3% answered incorrectly regarding treatment duration. These findings indicate areas that may benefit from targeted health education on prevention, early detection, and treatment adherence.

Sources of Information Among Respondents

Table 5 presents students' reported sources of information about TB. Most students (93.2%) reported no previous TB infection, and 88.6% had heard about TB. Information was obtained from healthcare professionals by 49.4% of students, social media by 40.8%, lecturers or teachers by 36.7%, and colleagues by 5.7%.

Table 5. Distribution of Students' Responses Regarding Sources of Information About Tuberculosis

Variable	category	n	%
History of previous tuberculosis (TB) infection	Yes	30	6.8
	No	409	93.2
Ever heard about tuberculosis (TB)	Yes	389	88.6
	No	50	11.4
Received information about TB from healthcare professionals	Yes	217	49.4
	No	222	50.6
Received information about TB from social media	Yes	179	40.8
	No	260	59.2
Received information about TB from lecturers/teachers	Yes	161	36.7
	No	278	63.3
Received information about TB from colleagues	Yes	25	5.7
	No	414	94.3

Behaviour of Respondents Regarding TB Prevention

TB prevention behaviours were grouped into indirect and direct transmission-prevention behaviours. Table 6 presents the distribution of these behaviours among students in Islamic boarding schools.

Table 6. Tuberculosis Prevention Behaviours Among Students in Islamic Boarding Schools

Variable	Category	(n)	(%)
Behaviour Prevention of Indirect Transmission			
Airing bedding in the sun	Always	108	24.6
	Sometimes	280	63.8
	Never	51	11.6
Handwashing practices	Yes	389	88.6
	No	50	11.4
Sleeping	Sleeping on a mattress/bed	388	88.4
	Sleeping on a mat	51	11.6
Direct Transmission Prevention Behaviour			
Disposed of sputum	Disposed of in the designated place	394	89.7
	Disposed of indiscriminately	45	10.3
Mask use while coughing	Always	69	15.7
	Sometimes	157	35.8
	Never	213	48.5
Covered mouth using a tissue/handkerchief	Yes	163	37.1
	No	276	62.9
Covered mouth using the elbow	Yes	299	68.1
	No	140	31.9

Table 6 shows gaps in several prevention behaviours. For indirect prevention, 11.6% of students never aired their bedding in the sun and 11.4% did not report handwashing practices. For direct prevention, 10.3% disposed of sputum indiscriminately, 48.5% never wore a mask when coughing, 62.9% did not cover their mouth with a tissue or handkerchief, and 31.9% did not cover their mouth with their elbow.

The association between students' knowledge and their TB prevention behaviour was analysed using the chi-square test and is presented in Table 7.

Table 7. Association Between Knowledge and Tuberculosis Prevention Behaviour Among Students in Islamic Boarding Schools

Knowledge	Bad n (%)	Good n (%)	Total n (%)	p-value	OR	95% CI
Bad	97 (46.6)	111 (53.4)	208 (100)	0.023	1.55	1.063–2.285
Good	83 (35.9)	148 (64.1)	231 (100)			

*No cells (0%) had an expected count of less than 5. The minimum expected count was 85.28.

As shown in Table 7, knowledge was significantly associated with prevention behaviour (Pearson chi-square test; $\chi^2(1) = 5.18$; $p = 0.023$). Students with poor knowledge had higher odds of poor prevention behaviour than students with good knowledge (OR = 1.55; 95% CI: 1.06–2.29). No cells had an expected count of less than 5, and the minimum expected count was 85.28, satisfying the expected cell-count assumption for the Pearson chi-square test. This exploratory bivariate association warrants further investigation; however, the cross-sectional design precludes causal conclusions about whether improving knowledge would improve prevention behaviour.

Environmental Factors

Environmental conditions in the two Islamic boarding schools are presented in Table 8. Both schools failed to meet the applicable standard for several environmental parameters.

Table 8. Environmental Conditions in the Islamic Boarding Schools

Environmental condition	Boarding school “A”	Boarding school “B”	Standard (Ministry of Health regulation No. 2 of 2023)
Average residential density (m ² /person)	2.19	2.45	9 m ²
Average ventilation area (%)	13.33	9.93	10%–20%
Average humidity (%)	66.5	68.4	40%–60%
Average room temperature (°C)	25.8	27.1	18–30
Average lighting (lux)	61.26	101.12	60 lux
Cleanliness	Inadequate	Unclean	Clean

The physical environmental conditions were evaluated against benchmarks established by Indonesian Ministry of Health Regulation No. 2 of 2023 (Table 8). Residential density in both institutions failed to meet the national threshold of ≥ 9 m² per person. Mean relative humidity in both the modern (66.5%) and traditional (68.4%) schools exceeded the recommended range of 40%–60%. Mean ventilation area met the benchmark of 10%–20% in the modern school (13.33%) but fell below it in the traditional school (9.93%). Mean room temperature in both schools remained within the acceptable range of 18–30°C. Mean natural lighting intensity met the minimum standard of ≥ 60 lux in both settings (61.26 lux in the modern school and 101.12 lux in the traditional school). However, room-level minimum values fell below the threshold, reaching 36.00 lux and 18.30 lux, respectively. Rooms in both schools were categorised as unclean on the basis of dust accumulation and potential contamination sources.

DISCUSSION

Xpert MTB/RIF (TCM) examination of 439 students selected on the basis of symptoms or contact history identified one positive case (0.2%), indicating a low active-case yield in this screening round. Because this was a one-time, symptom/contact-based screening without latent TB testing or longitudinal follow-up, transmission risk in these Islamic boarding schools remains uncertain and cannot be inferred from this yield alone. Students nonetheless represent a vulnerable group for TB (17). Adolescents may acquire TB through exposure to infectious individuals, including family or household contacts (27). Risk may also be increased in high-burden communities and among individuals with factors that compromise immune function, including substance use (28,29). Older children and adolescents may be more capable of transmitting TB because they can develop adult-type pulmonary disease and produce infectious aerosols (30).

This study found high dormitory occupancy, with 22–28 students per room in one school, which may increase transmission potential. A study in China showed that outbreaks can occur after prolonged periods of undetected index cases; therefore, consistent surveillance and screening are important for prevention (19). In addition to active screening, vaccination is an important component of TB prevention, particularly in children and adolescents (17). Cough was reported by the student with the positive result. In an Indian active case-finding study among nomadic populations, 80% of presumptive TB cases reported cough and 20% reported fever and significant weight loss (31).

In this study, students' knowledge of tuberculosis was significantly associated with prevention behaviour in an unadjusted bivariate analysis ($p = 0.023$). Given the cross-sectional design and the absence of adjustment for potential confounders such as age, sex, and school-specific factors, this association should be interpreted as exploratory rather than causal and does not establish that improving knowledge would lead to improved prevention behaviour. Adolescents may have limited understanding of TB symptoms, risk factors, and modes of transmission. The CDC states that TB can spread through the air when a person with active pulmonary or laryngeal TB coughs, speaks, or sings (32). Consequently, exposure to a person with active TB in a shared indoor space can create transmission risk; household-contact studies have reported substantial

transmission among close contacts (33–36). Some students understood the definition of TB, aetiology and transmission, but misconceptions about heredity and reinfection remained. These misconceptions could compromise prevention strategies in Islamic boarding schools.

Research shows that students' attitudes towards TB prevention are associated with their knowledge, while limited knowledge may contribute to ineffective self-protection against TB (24,37,38). Other studies have also linked limited TB knowledge with increased vulnerability. Differences in TB knowledge have been reported between female and male students, including awareness of symptoms such as haemoptysis. These findings support enhanced health education programmes in Islamic boarding schools, including structured counselling, community-based educational media, and health cadre training.

Such initiatives may address knowledge gaps, correct misconceptions, and strengthen students' competencies in TB prevention and control within Islamic boarding schools. Integrated TB/HIV services are also important for children and populations at high risk of TB/HIV (39). These findings differ from those of a Chinese high-school study in which most students demonstrated good knowledge and practices (82.09% and 83.25%, respectively). TB information may be obtained through multiple media sources both within and outside school settings (22).

Students in Islamic boarding schools showed gaps between TB knowledge and preventive practices, particularly cough etiquette and mask use. This discrepancy highlights the importance of translating knowledge into sustained preventive behaviour. Previous studies have likewise linked suboptimal attitudes and personal-hygiene practices with vulnerability to TB transmission (11,12).

Research shows that adolescents have poor cough etiquette and inconsistent mask use, which increases the potential for TB transmission. Furthermore, the transmission of tuberculosis is exacerbated by the following factors: the presence of active cases of the disease, the absence of adequate ventilation in the room, and the high residential density of the area (13,40). Educational and regulatory approaches in Islamic boarding schools are important. Teachers and caregivers must set a good example, community-based health regulations must be developed, and students must be empowered through health cadre programmes. These efforts are expected to raise awareness and form sustainable preventive habits in TB prevention.

In this study, the symptom/contact-based screening algorithm combined with Xpert MTB/RIF testing identified one bacteriologically positive case among the 439 students tested. As this study did not evaluate diagnostic accuracy against a reference standard, this finding should be regarded as an observation of screening yield rather than evidence of the test's diagnostic performance. Xpert MTB/RIF's sensitivity and utility for early TB detection in high-risk congregate settings have been established in prior diagnostic accuracy studies. In the absence of intervention, there is a risk of transmission due to prolonged exposure. The research conducted at the boarding school in Madura indicates that 30% of the 100 adolescent students in attendance are infected with latent tuberculosis (41). Another study at a boarding schools has revealed that 46 active cases were identified among 258 students and 15 teachers, yielding an attack rate of 16.8% (42). These findings illustrate the potential for transmission in congregate school settings. Identification of an active TB case requires appropriate public-health follow-up, including contact investigation and assessment for TB preventive treatment where indicated. Xpert MTB/RIF is useful for detecting TB in high-risk settings such as Islamic boarding schools; however, this study did not evaluate diagnostic accuracy against an independent reference standard.

Environmental and behavioural conditions in Islamic boarding schools may increase TB transmission potential. In this study, occupancy density, relative humidity, ventilation in one school, and cleanliness did not meet the applicable benchmarks, although mean temperature and lighting met the specified standards. High occupancy has been identified as an important environmental risk factor for TB transmission (7). Inadequate ventilation can increase the concentration and persistence of infectious aerosols indoors. Studies have reported higher TB risk in dwellings with limited window area or poor ventilation compared with better-ventilated housing (7,10,12,13). Relative humidity in both boarding schools (66.5%–68.4%) exceeded the recommended range of 40%–60%. Elevated humidity may contribute to conditions that favour persistence of infectious aerosols (9).

Poor ventilation and high occupancy can increase the concentration of airborne infectious particles. In the present study, high occupancy density, inadequate ventilation in one school, and elevated humidity may contribute to an environment with increased TB transmission potential. These findings support consideration of structural and environmental interventions consistent with infection-prevention principles (43). In correctional facilities, TB-control measures have included reducing occupancy density and improving ventilation (15). Adequate indoor ventilation is an important component of TB outbreak control (44).

TB transmission is influenced by both environmental conditions and preventive behaviours. Gaps in prevention practices may compound risks associated with overcrowding, high humidity, and inadequate ventilation in boarding-school settings.

Epidemiological Implications

Conditions in Islamic boarding schools may create a microclimate that reduces the inactivation of *Mycobacterium tuberculosis* by ultraviolet light. TB control strategies should distinguish between immediate measures, such as screening and mask provision, and longer-term interventions, such as improving ventilation, reducing dormitory density, and optimising lighting. TB control requires action by multiple stakeholders and cannot be delegated solely to students. Priority should be given to prompt identification and referral of symptomatic students through routine active case finding. Source-control measures, including immediate mask use and, where feasible, temporary isolation of symptomatic students pending evaluation, should follow to limit transmission. Environmental controls, particularly improved dormitory ventilation and reduced occupancy density, are essential to reduce the concentration of infectious droplet nuclei indoors. Appropriate respiratory protection for staff and close contacts during high-risk interactions should complement these measures. General hygiene practices, such

as handwashing and sanitiser provision, remain useful supplementary institutional measures but should not be regarded as primary controls for airborne TB transmission.

Local primary health centres have an important role in providing clear referral pathways, facilitating contact tracing, and offering guidance on case management. Parental involvement is also important. Institutions should prioritise prompt symptom-based identification and referral, source control through mask use for symptomatic students, and structural improvements to ventilation and occupancy density. A consistent supply of masks and, where relevant, respiratory protection for staff should be ensured as a core measure, while hand sanitisers and general hygiene supplies should remain supplementary components of TB control.

When implementing environmental improvements, infrastructure costs and institutional planning should be considered. Low-cost measures should be prioritised before major renovations or ventilation upgrades.

To support a sustainable programme, schools and public-health authorities should establish practical, measurable indicators, including the proportion of students screened, the proportion of symptomatic students successfully tested, the proportion receiving TB education, and the frequency of environmental cleaning. Longer-term indicators should assess compliance with ventilation and lighting standards and reductions in overcrowding. Monitoring these indicators may help administrators and health authorities evaluate programme implementation and identify emerging risk clusters.

Study Limitations

This study has several limitations. First, the cross-sectional design and purposive selection of only two Islamic boarding schools (pesantren) with known previous TB cases in Banyumas Regency may introduce selection bias and limit the generalisability of the findings to schools without previous TB cases or to Indonesia more broadly. Second, reliance on self-reported behavioural data may introduce social desirability bias and institutional pressure, potentially prompting students to over-report desirable practices, such as handwashing, mask use, and cough etiquette, and under-report unfavourable behaviours. Third, the absence of latent TB infection (LTBI) testing limits assessment of overall exposure history or recent transmission dynamics; therefore, the low yield of active cases detected through Xpert MTB/RIF screening should be interpreted cautiously. Fourth, the absence of adjusted effect estimates or multivariable analysis means that the knowledge-behaviour association in Table 7 is an unadjusted bivariate estimate and could not account for potential confounders such as age, sex, school-specific variables, previous exposure, or peer norms. Finally, transmission dynamics cannot be inferred definitively from a single confirmed active TB case. The rifampicin-resistance result was not reported, so no inference regarding rifampicin resistance can be made from this study report.

CONCLUSION

The study identified one active TB case among the students and documented gaps in preventive behaviours and suboptimal environmental conditions that may increase the potential for TB transmission. Knowledge and preventive practices, particularly cough etiquette and mask use, showed important gaps, while dormitory conditions included overcrowding, inadequate ventilation in one school, high humidity, and inadequate cleanliness. Because the study included only two schools and used a cross-sectional design, it cannot establish a causal relationship between knowledge and behaviour or between environmental conditions and TB transmission.

The findings support continued prevention measures, surveillance, and environmental health improvements. TB prevention programmes in boarding schools should include health education, active case finding, improved cough etiquette, and appropriate mask use among symptomatic students. Environmental measures should focus on improving dormitory ventilation, reducing occupancy density, and monitoring environmental conditions. In this study, targeted active case finding identified one active TB case among 439 tested students, alongside behavioural gaps and suboptimal environmental conditions in the two participating schools.

These findings indicate a need for continued screening, behavioural support, and environmental monitoring in boarding-school settings. TB control programmes should prioritise prompt identification and referral of symptomatic students through routine active case finding. Source-control measures, including immediate mask use and, where feasible, temporary isolation of symptomatic students pending evaluation, should be used to limit transmission. Environmental controls, particularly improved dormitory ventilation and reduced occupancy density, are important for reducing the concentration of infectious droplet nuclei indoors. Appropriate respiratory protection for staff and close contacts during high-risk interactions should complement these measures. General hygiene practices, such as handwashing and sanitiser provision, remain useful supplementary institutional measures but should not be regarded as primary controls for airborne TB transmission. Further longitudinal and multisite research is needed to assess the feasibility and effectiveness of routine active case finding in pesantren.

DECLARATIONS

Author contributions: Author contributions were mapped to the CRediT taxonomy on the basis of the contributions reported in the submitted manuscript: DSS: Conceptualization, Formal analysis, Investigation, Writing – original draft. SPM: Supervision, Validation, Writing – original draft. SS: Writing – review & editing. BW: Formal analysis, Investigation. MAR: Writing – original draft, Writing – review & editing.

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Declaration of Generative AI And AI-Assisted Technologies in the Writing Process: The authors used ChatGPT Version GPT-6 solely to improve the English language, grammar, clarity, and readability of the manuscript. All scientific content, including the study design, methodology, data analysis, interpretation of findings, and conclusions, was independently developed and written by the authors. To ensure the accuracy and integrity of the manuscript, the authors carefully reviewed and verified all AI-assisted

language revisions to ensure that the original meaning, scientific accuracy, and intended interpretations remained unchanged. ChatGPT was not used to generate scientific content, analyze data, or formulate research conclusions. The authors take full responsibility for the accuracy, originality, integrity, and final content of the manuscript.

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REFERENCES

1. WHO. Global Tuberculosis Report 2024. 2024. Available from: <https://www.who.int/teams/global-programme-on-tuberculosis-and-lung-health/tb-reports/global-tuberculosis-report-2024>
2. Dodd PJ, Yuen CM, Sismanidis C, Seddon JA, Jenkins HE. The global burden of tuberculosis mortality in children: a mathematical modelling study. *Lancet Glob Health*. 2017;5(9):e898–e906. doi: [https://doi.org/10.1016/S2214-109X\(17\)30289-9](https://doi.org/10.1016/S2214-109X(17)30289-9)
3. Ministry of Health Republic of Indonesia. Indonesia Health Profile 2025. 2026. Available from: <https://kemkes.go.id/eng/profil-kesehatan-indonesia-2025>
4. Saktiawati AMI, Probandari A. Tuberculosis in Indonesia: challenges and future directions. *Lancet Respir Med*. 2025;13(8):669–671. doi: [https://doi.org/10.1016/S2213-2600\(25\)00168-7](https://doi.org/10.1016/S2213-2600(25)00168-7)
5. Coleman M, Martinez L, Theron G, Wood R, Marais B. Mycobacterium tuberculosis transmission in high-incidence settings—new paradigms and insights. *Pathogens*. 2022;11(11):1228. doi: <https://doi.org/10.3390/pathogens11111228>
6. Dinas Kesehatan Kabupaten Banyumas. Mas Robi Gemar Bertasbih (Banyumas Zero TBC dengan Gerakan Masyarakat Berantas Tuberkulosis Sampai Habis) sebagai Upaya Pemberdayaan Masyarakat dalam Pencegahan dan Pengendalian TBC di Kab. Banyumas. Pemerintah Kabupaten Banyumas. 2024. Available from: <https://dinkes.banyumaskab.go.id/news/49905/mas-robi-gemar-bertasbih-banyumas-zero-tbc-dengan-gerakan-masyarakat-berantas-tuberkulosis-sampai-habis-sebagai-upaya-pemberdayaan-masyarakat-dalam-pencegahan-dan-pengendalian-tbc-di-kab-banyumas>
7. Jannah RZ, Azizah R, Jalaludin JB, Sulistyorini L, Lestari KS. Meta-analysis study: environmental risk factors of tuberculosis (TB). *Jurnal Kesehatan Lingkungan*. 2023;15(2):84–91. doi: <https://doi.org/10.20473/jkl.v15i2.2023.84-91>
8. Batistha ZI, Novi MAC, Yusi RL, Yuhbaba ZN. Analysis of indoor environmental health factors related to the incidence of tuberculosis in children in Jember District. *Jurnal Kesehatan dr. Soebandi*. 2025;13(1). doi: <https://doi.org/10.36858/jkds.v13i1.782>
9. Siddalingaiah N, Chawla K, Nagaraja SB, Hazra D. Risk factors for the development of tuberculosis among the pediatric population: a systematic review and meta-analysis. *Eur J Pediatr*. 2023;182(7):3007–3019. doi: <https://doi.org/10.1007/s00431-023-04988-0>
10. Ayu F, Putri A, Nugraha P, BM S, Kesehatan BP, Perilaku I, et al. Faktor-faktor yang mempengaruhi praktik PHBS pencegahan penyakit TB paru pada santri di Pondok Pesantren Nurul Hasan Kabupaten Magelang. 2017;5:2356–3346. doi: <https://doi.org/10.14710/jkm.v5i3.17285>
11. Adriansyah AA. Keterkaitan antara sanitasi pondok pesantren dengan kejadian penyakit yang dialami santri di Pondok Pesantren Sunan Drajat. *MTPH Journal*. 2017.
12. Laili N, Roi'sah, Sunanto, Handayani E. Pemberdayaan santri dalam perilaku hidup bersih dan sehat (PHBS) dalam upaya pencegahan penyakit tuberculosis di Pondok Pesantren Probolinggo (Empowering Islamic boarding school students in clean and healthy living practices (PHBS) as part of efforts to prevent tuberculosis at the Probolinggo Islamic boarding school). *Jurnal Bhakti Civitas Akademika*. 2022.
13. Mohidem NA, Hashim Z, Osman M, Muharam FM, Elias SM, Shaharudin R. Environment as the risk factor for tuberculosis in Malaysia: a systematic review of the literature. *Rev Environ Health*. 2021;36(4):493–499. doi: <https://doi.org/10.1515/reveh-2020-0096>
14. Xu J, Wang G, Zhang Y, Zhang G, Xing J, Qi L, et al. An outbreak of tuberculosis in a middle school in Henan, China: epidemiology and risk factors. *PLoS One*. 2019;14(11):1–13. doi: <https://doi.org/10.1371/journal.pone.0225042>
15. Naning H, Al-Darraj HAA, McDonald S, Ismail NA, Kamarulzaman A. Modelling the impact of different tuberculosis control interventions on the prevalence of tuberculosis in an overcrowded prison. *Asia Pac J Public Health*. 2018;30(3):235–243. doi: <https://doi.org/10.1177/1010539518757229>
16. Deol AK, Shaikh N, Middelkoop K, Mohlamonyane M, White RG, McCreesh N. Importance of ventilation and occupancy to Mycobacterium tuberculosis transmission rates in congregate settings. *BMC Public Health*. 2022;22(1):1772. doi: <https://doi.org/10.1186/s12889-022-14133-5>
17. Zhou J, Ma X, Lu TJ, Zhuang Y, Li JL, Chen H. Epidemiological characteristics of pulmonary tuberculosis among students in Guizhou, China: a retrospective study from 2010 to 2020. *BMJ Open*. 2023;13(5):1–9. doi: <https://doi.org/10.1136/bmjopen-2023-072010>
18. Busatto C, Bierhals DV, Vianna JS, Silva PEA, Possuelo LG, Ramis IB. Epidemiology and control strategies for tuberculosis in countries with the largest prison populations. *Rev Soc Bras Med Trop*. 2022;55. doi: <https://doi.org/10.1590/0037-8682-0060-2022>
19. Bao H, Kui L, Zikang W, Xiaomeng W, Chengliang C, Tieniu H, et al. Tuberculosis outbreaks among students in mainland China: a systematic review and meta-analysis. *BMC Infect Dis*. 2019;19:972. doi: <https://doi.org/10.1186/s12879-019-4573-3>
20. Hendawati, Kumalasari I, Irmwartini, Lindwati. Analysis of factors influencing clean and healthy (PHBS) practices to prevent pulmonary TB among students at Islamic boarding school Palembang. 2024.
21. Abbas A, S1 P, Masyarakat K, Ilmu I, Bhakti K, Kediri W. Skrining tuberculosis (TB) pada santri Pondok Pesantren X Kota Kediri (Tuberculosis (TB) screening among students of Islamic boarding school X in Kediri City). 2025;2(2):74–80. doi: <https://doi.org/10.54883/fs9q483>
22. Dai X, Li S, Song S, Chen M, Xu H, Li X, et al. Knowledge, attitudes, and practice toward tuberculosis in high school students in Qingdao, China. *J Infect Dev Ctries*. 2024;18(3):427–434. doi: <https://doi.org/10.3855/jidc.18312>
23. Kaaffah S, Kusuma IY, Renaldi FS, Pratiwi ADE, Bahar MA, Lestari YE. Knowledge, attitudes, and perceptions of tuberculosis in Indonesia: a multi-center cross-sectional study. *Infect Drug Resist*. 2023;16:1787–1800. doi: <https://doi.org/10.2147/IDR.S404171>

24. Rahman M, Kurniawan FD, Habibie YA, Arliny Y, Maulina N. The relationship between tuberculosis knowledge and the attitudes and behaviors of Dayah students. *Journal of International Surgery and Clinical Medicine*. 2024;4(2):21–25. doi: <https://doi.org/10.51559/jiscm.v4i2.60>
25. Shewade HD, Pradeep SK, Ravichandran P, Kiruthika G, Shah AN, Vadera B. Active case-finding for TB in India: assessment of scale and quality benchmarks, time taken and use of rapid molecular diagnostic tests. *PLOS Glob Public Health*. 2025;5(10):e0005103. doi: <https://doi.org/10.1371/journal.pgph.0005103>
26. Vonasek B, Ness T, Takwoingi Y, Kay AW, Wyk SS, Ouellette L, et al. Screening tests for active pulmonary tuberculosis in children. *Cochrane Database Syst Rev*. 2021;2021(6). doi: <https://doi.org/10.1002/14651858.CD013693.pub2>
27. Lancella L, Vecchio A, Chiappini E, Tadolini M, Cirillo D, Tortoli E, et al. How to manage children who have come into contact with patients affected by tuberculosis. *J Clin Tuberc Other Mycobact Dis*. 2015;1:1–12. doi: <https://doi.org/10.1016/j.ijctube.2015.07.002>
28. Park J, Yoon JH, Ki HK, Han K, Kim H. Lifestyle changes and risk of tuberculosis in patients with type 2 diabetes mellitus: a nationwide cohort study. *Front Endocrinol (Lausanne)*. 2022;13:1009493. doi: <https://doi.org/10.3389/fendo.2022.1009493>
29. Snow KJ, Cruz AT, Seddon JA, Ferrand RA, Chiang SS, Hughes JA, et al. Adolescent tuberculosis. *Lancet Child Adolesc Health*. 2020;4(1):68–79. doi: [https://doi.org/10.1016/S2352-4642\(19\)30337-2](https://doi.org/10.1016/S2352-4642(19)30337-2)
30. Turner RD. Cough in pulmonary tuberculosis: existing knowledge and general insights. *Pulm Pharmacol Ther*. 2019. doi: <https://doi.org/10.1016/j.pupt.2019.01.008>
31. Ramalingam S, Senthil R, Dhasaram P, Bajwin F. Active case finding of tuberculosis among nomads and semi-nomads in Puducherry. *J Family Med Prim Care*. 2024;13(1):243–248. doi: https://doi.org/10.4103/jfmpc.jfmpc_1032_23
32. CDC. Tuberculosis: Causes and How It Spreads. CDC. 2025. Available from: <https://www.cdc.gov/tb/causes/index.html>
33. Rahmawati E, Nurhayati E. Risk of pulmonary tuberculosis transmission among household contacts. *ELECTRON (Journal of Science and Technology)*. 2025;7(1):9–16. Available from: <https://journal.ahmareduc.or.id/index.php/electron>
34. Kigozi NG, Heunis JC, Engelbrecht MC, Janse van Rensburg AP, Rensburg HCJD. Tuberculosis knowledge, attitudes and practices of patients at primary health care facilities in a South African metropolitan: research towards improved health education. *BMC Public Health*. 2017;17(1):795. doi: <https://doi.org/10.1186/s12889-017-4825-3>
35. Laycock KM, Enane LA, Steenhoff AP. Tuberculosis in adolescents and young adults: emerging data on TB transmission and prevention among vulnerable young people. *Trop Med Infect Dis*. 2021;6(3):148. doi: <https://doi.org/10.3390/tropicalmed6030148>
36. DeLuca A, Dhumal G, Paradkar M, Suryavanshi N, Mave V, Kohli R, et al. Addressing knowledge gaps and prevention for tuberculosis-infected Indian adults: a vital part of elimination. *BMC Infect Dis*. 2018;18(1):202. doi: <https://doi.org/10.1186/s12879-018-3116-7>
37. Rejeki DSS, Wijayanti SPM, Radi, Solikhah, Eil LDA. Prevalence and determinants of tuberculosis Mantoux test on children under five in Banyumas District. *E3S Web Conf*. 2025;609:04008. doi: <https://doi.org/10.1051/e3sconf/202560904008>
38. Ulfah IN. Hubungan antara pengetahuan dan sikap dengan perilaku pencegahan penularan tuberculosis pada santri putri Pondok Pesantren Modern Islam Assalaam Surakarta Jawa Tengah. 2021. Universitas Muhammadiyah Surakarta.
39. Mandalakas AM, Kay AW, Bacha JM, Devezin T, Golin R, Simon KR, et al. Tuberculosis among children and adolescents at HIV treatment centers in Sub-Saharan Africa. *Emerg Infect Dis*. 2020;26(12):2933–2943. doi: <https://doi.org/10.3201/EID2612.202245>
40. Lee JY, Kwon N, Goo GY, Cho SI. Inadequate housing and pulmonary tuberculosis: a systematic review. *BMC Public Health*. 2022;22(1):622. doi: <https://doi.org/10.1186/s12889-022-12879-6>
41. Ananto MA, Setyoningrum RA, Lestari P. Prevalence and risk factors of LTBI at Madura boarding school as a high-risk congregate setting. *JUXTA: Jurnal Ilmiah Mahasiswa Kedokteran Universitas Airlangga*. 2024;15(2):76–82. doi: <https://doi.org/10.20473/juxta.v15i22024.76-82>
42. Ma MJ, Yang Y, Wang HB, Zhu YF, Fang LQ, An XP, et al. Transmissibility of tuberculosis among school contacts: an outbreak investigation in a boarding middle school, China. *Infect Genet Evol*. 2015;32:148–155. doi: <https://doi.org/10.1016/j.meegid.2015.03.001>
43. Pelissari DM, Saita NM, Monroe AA, DQF. Environmental factors associated with the time to tuberculosis diagnosis in prisoners in São Paulo, Brazil. *Am J Infect Control*. 2022;50(11):1246–1252.
44. Du CR, Wang SC, Yu MC, Chiu TF, Wang JY, Chuang PC, et al. Effect of ventilation improvement during a tuberculosis outbreak in underventilated university buildings. *Indoor Air*. 2020;30(3):422–432. doi: <https://doi.org/10.1111/ina.12639>



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