Literature Review: Factors Affecting Tuberculosis Recurrence in Indonesia

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Abstract.

Tuberculosis (TB) remains a significant public health challenge in Indonesia, with relapse contributing substantially to the ongoing disease burden. This systematic literature review aims to identify and synthesize factors affecting TB recurrence in Indonesia, providing insights for targeted interventions. The study employed a comprehensive search across Google Scholar, PubMed, and ScienceDirect using keywords in both English and Bahasa Indonesia, focusing on articles published between 2015 and 2025. A total of 10 primary research articles meeting the inclusion criteria were analyzed, encompassing retrospective, cohort, and cross-sectional designs. Data were extracted on variables such as behavioral, socioeconomic, healthcare, biological, and environmental factors, then synthesized to determine their association with TB relapse. Findings consistently highlight smoking habits, medication non-adherence, low education, inadequate housing ventilation, comorbidities like diabetes, and household contact with TB patients as significant risk factors. Despite heterogeneity in study methodologies, these results underscore the multifaceted nature of TB relapse determinants. The review concludes that integrated strategies addressing behavioral, socioeconomic, and environmental factors are crucial for TB control efforts in Indonesia. Future research should focus on longitudinal and multicenter studies to establish causality and evaluate intervention efficacy. These insights are vital to inform policies aimed at reducing TB recurrence and achieving Indonesia's goal of TB elimination by 2030.

Keywords: *Tuberculosis Recurrence; Indonesia; Risk Factors; Socioeconomic Determinants and Treatment Adherence.*

I. INTRODUCTION

Tuberculosis (TB) remains one of the most formidable global public health challenges, primarily due to its highly contagious nature and significant mortality rates. Caused by the bacterium *Mycobacterium tuberculosis*, TB predominantly affects the lungs but can also impact other organs. It's easy airborne transmission—requiring only a few bacterial particles dispersed through coughing or sneezing—ensures TB's persistent threat to both global and national health [1], [2]. This high transmissibility contributes to a substantial burden of cases across various countries, including Indonesia.Indonesia plays a crucial role in global TB control efforts, ranking second worldwide in terms of the highest TB burden. The 2024 Global Tuberculosis Report from WHO indicates that Indonesia accounted for approximately 10% of global TB cases in 2023, positioning it just below India [3]. The global trend of TB cases, including those in Indonesia, continues to show an annual increase—rising from 10.1 million people in 2020 to 10.8 million in 2024 [3], [4]. These figures underscore that TB remains a significant, uncontrolled health burden demanding serious attention.The rising trend in TB cases is not solely attributed to new infections but also to the phenomenon of TB relapse. TB relapse is defined as a condition where a patient, previously declared cured after completing treatment, is re-diagnosed with *Mycobacterium tuberculosis* and must undergo another treatment regimen [5]. This recurrence serves as a critical indicator of long-term treatment success, with an average occurrence 18 months after initial therapy completion [5].

Data from the World Bank suggests that a portion of Indonesia's surge in TB cases stems from relapses, reinforced by findings that only 34% of TB patients complete treatment without experiencing a relapse within two years [6], [7]. This situation highlights significant challenges in patient adherence and the effectiveness of post-treatment monitoring in Indonesia. TB relapse cases are not just individual concerns; they also reflect systemic failures in TB management. Patients experiencing relapse are at a high risk of developing drug resistance, particularly Multidrug-Resistance Tuberculosis (MDR-TB), which involves resistance to rifampicin and isoniazid [8], [9]. A meta-analysis by Xi et al. [10] demonstrated that a history of TB increases the risk of MDR-TB by 6-fold (OR = 6.078; 95% CI: 2.903–12.725), and previous TB therapy history further elevates MDR-TB risk by 5.4-fold (OR = 5.427; 95% CI: 3.469–8.490). Furthermore, relapse increases the risk of severe complications, especially with delayed diagnosis or pre-existing lung damage.

Approximately 50% of pulmonary TB survivors may develop post-TB lung disease (PTLD), characterized by fibrosis and bronchiectasis, which worsen respiratory symptoms upon recurrence [11], [12].

For the healthcare system, relapse escalates treatment costs, prolongs hospitalization, and increases the demand for more expensive, second-line drugs with more severe side effects. It also has the potential to boost TB transmission within communities, as relapsing patients often become active sources of infection again [13].Given these pressing issues, this study aims to identify and summarize the factors contributing to Tuberculosis (TB) relapse in Indonesia through a systematic literature review. This research is expected to provide comprehensive insights and knowledge regarding risk factors from various aspects—ranging from treatment adherence, socioeconomic conditions, healthcare services, biological factors, to the physical environment—all relevant to the Indonesian context. The novelty of this study lies in its synthesis of up-to-date and Indonesia-specific data, which is anticipated to serve as a foundation for policymakers in formulating preventive strategies, strengthening TB control systems, and acting as a valuable reference for future research. Ultimately, this effort supports Indonesia's commitment to achieving TB elimination by 2030, with a targeted incidence reduction to 65 per 100,000 population [14].

II. METHODS

Study Type and Design

This study employed a literature review method, specifically a systematic review approach, to comprehensively gather, analyze, and synthesize existing literature relevant to the factors influencing tuberculosis (TB) relapse in Indonesia. A systematic review is crucial for identifying gaps in current knowledge and providing robust evidence for public health interventions by critically appraising and synthesizing findings from multiple studies [15]. This method ensures a transparent and reproducible process for selecting and evaluating relevant research [16].

Data Sources and Search Strategy

Data extraction commenced with a systematic search across three primary electronic databases: Google Scholar, PubMed, and ScienceDirect. To ensure a comprehensive retrieval of relevant articles, a combination of Boolean operators (AND, OR) was utilized with predefined keywords in both English and Bahasa Indonesia. The English keywords included "tuberculosis recurrence," "TB relapse," "factors," and "Indonesia." Correspondingly, the Bahasa Indonesia keywords were "kekambuhan," "tuberkulosis," "faktor," and "Indonesia." This dual-language search strategy was implemented to maximize the identification of studies published locally within Indonesia, which might not always be indexed in international databases. The search focused on articles published within a ten-year window, from 2015 to 2025, ensuring the inclusion of recent and highly relevant research to reflect current epidemiological trends and interventions in TB relapse [17].

Study Selection Process

The retrieved articles underwent a rigorous two-stage selection process: screening and eligibility, guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [18], [19]. The initial search yielded a total of 2,244 articles: 2,140 from Google Scholar, 79 from PubMed, and 25 from ScienceDirect. In the screening phase, articles were filtered based on the following inclusion criteria: (1) no duplication, (2) availability of full-text PDF, (3) publication between 2015 and 2025, and (4) not being another literature review. Mendeley reference management software aided in identifying and removing 4 duplicate articles, leaving 2,240 articles for initial screening. This stage excluded 2,202 articles that did not meet the screening criteria, leaving 42 articles for the subsequent eligibility assessment.In the eligibility phase, the remaining 42 articles were rigorously assessed against stricter criteria: (1) relevance to the study topic (factors influencing TB relapse), (2) utilization of quantitative research methods, and (3) research conducted specifically within Indonesia. This meticulous process ensured that only primary research articles with empirical data pertinent to the Indonesian context were included. Ultimately, 32 articles were excluded in this stage for not meeting the eligibility criteria, resulting in a final selection of 10 articles for in-depth analysis. The entire article selection process, including the number of articles identified, screened,

assessed for eligibility, and finally included, is visually represented in a PRISMA flow diagram (Figure 1), ensuring transparency and replicability [19].

Data Extraction and Synthesis

Data from the 10 selected articles were systematically extracted and tabulated (Table 1) to facilitate comprehensive analysis. The extracted information included the researchers, country of study, methodology (study design, sample size, data collection, and analysis techniques), study objectives, and key findings. The extracted findings, particularly the statistical results (e.g., p-values, odds ratios, hazard ratios, confidence intervals), were critically appraised and then synthesized to identify recurring and significant factors associated with TB relapse in Indonesia. This synthesis involved categorizing the identified factors into distinct aspects such as behavioral, socioeconomic, healthcare, biological, and environmental, as presented in Table 2. This structured approach allowed for a clear and organized presentation of the accumulated evidence, forming the basis for the discussion of factors influencing TB relapse.

III. RESULT AND DISCUSSION

Results

Table 1. Literature Review Results

Researchers	Country	Method	Purpose	Result
Ratnawati et al., (2022)	Indonesia	A retrospective descriptive study with 391 samples, data from medical records, was analyzed using the Spearman correlation test.	This study aims to determine the relationship between patient characteristics (age, gender, education level, occupation, and smoking habits) and recurrence in patients with pulmonary tuberculosis at RSI PKU Muhammadiyah Pekajangan, Pekalongan.	The Spearman test results showed a significant relationship between age (p = 0.001), gender (p = 0.002), education (p = 0.018), and smoking habits (p = 0.027) with pulmonary TB recurrence, while employment status did not show a significant relationship (p = 0.562).
Sukmaningtyas et al., (2016)	Indonesia	This study is a retrospective cohort study with 904 purposively selected samples from 3,418 TB cases in Bantul Regency in 2003–2014.	This study aims to identify factors associated with pulmonary tuberculosis recurrence. The main focus of the study is to determine which variables can influence the likelihood of recurrence after patients are declared cured or experience treatment failure.	It was found that male gender (p = 0.17), age >40 years (p = 0.59), and low income (p = 0.11) were not predictors of TB recurrence. Conversely, hospitalization (p = 0.00), lack of sputum conversion (p = 0.00), treatment failure (HR = 0.49; 95% CI: 0.37–0.64), and treatment duration <6 months (HR = 0.008; 95% CI: 0.00–0.07) were significantly associated with recurrence. Of the 904 patients, 56 (6.18%) experienced relapse, with an average of 17 months after the first treatment was completed.
Yunita et al., (2020)	Indonesia	This study is a descriptive correlational study with a cross-sectional approach on 40 respondents at the Paru Center Aulia Hospital, using accidental sampling and analyzed with the chi-square test.	This study aims to determine the relationship between medication adherence and family motivation with the recurrence of pulmonary TB.	It was found that medication adherence (p = 0.041) and family motivation (p = 0.001) had a significant relationship with pulmonary TB recurrence.
Nurwanti et al., (2016)	Indonesia	This study used a case control design with 32 respondents selected purposively, and analyzed using the chi-square test to examine the relationship	This study aims to identify host and environmental factors associated with pulmonary TB relapse in community health centers in	Recurrence of pulmonary TB was significantly associated with adherence to previous treatment (p = 0.005; OR = 13.00), floor type (p = 0.011; OR = 11.667), and the

		between host and environmental factors and pulmonary TB recurrence.	Semarang City.	type of wall of the house (p = 0.005; OR = 13.00).
Jaya et al., (2017)	Indonesia	This study is a cross-sectional study with total sampling of data on pulmonary TB relapse at the South Sumatra Specialized Lung Hospital in 2015–2016, analyzed using the chi-square test.	The purpose of this study was to identify risk factors associated with pulmonary tuberculosis relapse at the South Sumatra Provincial Lung Hospital in 2016.	It was found that education (p = 0.017; OR = 4.2) and smoking history (p = 0.045; OR = 3.2) were significantly associated with pulmonary TB recurrence, while age, gender, and occupation showed no association.
Tumiwa et al., (2023)	Indonesia	This study is a *cross-sectional study* with a total population of 40 patients with relapsed pulmonary TB at Amurang Hospital, using a questionnaire and analyzed with a chi-square test.	The purpose of this study is to find out the determining factors related to relapse in patients with pulmonary tuberculosis at Amurang Hospital.	There was a significant association between medication adherence (ρ = 0.000), smoking behavior (ρ = 0.010), and home physical environment conditions (ρ = 0.000) and pulmonary TB recurrence.
Ulfa et al., (2023)	Indonesia	This study is a retrospective descriptive study with a total sampling of 22 patients with recurrent pulmonary TB at the Jambi City Health Center in 2020–2022, analyzed univariately.	This study aims to find out the overview of risk factors that contribute to the incidence of pulmonary TB recurrence at the Jambi City Health Center during the 2020–2022 period.	It was found that most patients with recurrent pulmonary TB at the Jambi City Community Health Center were men aged >34 years, with a high school education, low socioeconomic status, a history of smoking, and supported by normal nutritional status, adequate housing, regular treatment, and good family support.
Karminiasih et al., (2016)	Indonesia	This study is a *case-control study* with 138 respondents who were randomly selected systematically from 11 health centers in Denpasar, analyzed using chi-square tests and logistic regression.	This study aims to determine the risk factors related to the recurrence of pulmonary TB patients in Denpasar City.	It was found that the recurrence of pulmonary TB in Denpasar City was significantly associated with comorbid diabetes mellitus, non-adherence to medication, exposure to cigarette smoke, home ventilation <10%, contact with TB patients living in the same household, and poor nutritional status.
Siburian et al., (2019)	Indonesia	This research is a quantitative study with a total sample of 30 respondents, using questionnaires and analyzed univariately and bivariately with the Chi-Square test.	The purpose of this study is to find out the factors that cause the recurrence of pulmonary tuberculosis cases in general.	It was found that family support was significantly associated with pulmonary TB recurrence (p = 0.01), while knowledge, history of medication adherence, and patient attitude did not show a significant association.
Kusumajaya et al., (2024)	Indonesia	This study is a *cross-sectional study* on 53 pulmonary TB patients at Depati Hamzah Pangkalpinang Hospital, using a questionnaire and analyzed with a chi-square test.	The purpose of this study was to determine the factors related to recurrence in pulmonary tuberculosis patients, such as age, education, smoking habits, and medication adherence.	There was a significant association between age (p = 0.001), education (p = 0.000), smoking habit (p = 0.000), and medication adherence (p = 0.000) to pulmonary TB recurrence.

Table 2. Summary of Risk Factors for TB Recurrence

Risk factor	Sources	Analysis Results
Smoking behavior/exposure to cigarette smoke	Rahmawati et al. (2022)	p = 0,027
	Jaya & Mediarti (2017)	p = 0,045; OR = 3,2
	Tumiwa et al. (2023)	p = 0,010
	Kusumajaya (2024)	p = 0,000
	Karmianingsih et al. (2016)	significant (AOR not specifically stated)
	Ulfa et al.	The majority of smokers (55.5%), descriptively significant
Medication adherence	Tumiwa et al. (2023)	p = 0,000
	Kusumajaya (2024)	p = 0,000
	Yunita et al. (2020)	p = 0,041
	Karmianingsih et al. (2016)	significant
Adherence to previous treatment	Nurwanti & Wahyono (2016)	p = 0,005; OR = 13,00
Low education	Ratnawati et al. (2022)	p = 0,018
	Jaya & Mediarti (2017)	p = 0,017; OR = 4,2
	Kusumajaya (2024)	p = 0,000
Family support	Yunita et al. (2020)	p = 0,001
	Siburian et al. (2019)	p = 0,01
Treatment in a hospital	Sukmaningtyas et al. (2016)	p = 0,00; HR = 0,81
No sputum conversion occurs	Sukmaningtyas et al. (2016)	p = 0,00; HR = 0,58
Duration of treatment < 6 months	Sukmaningtyas et al. (2016)	HR = 0,008
Age	Ratnawati et al. (2022)	p = 0,001
	Kusumajaya (2024)	p = 0,001
Comorbidities (DM)	Karminiasih et al. (2016)	AOR = 9,6
Poor nutritional status	Karminiasih et al. (2016)	AOR = 2,8
Home ventilation <10%	Karminiasih et al. (2016)	AOR = 3,4
Types of house flooring	Nurwanti & Wahyono (2016)	p = 0,011; OR = 11,667
Types of house walls	Nurwanti & Wahyono (2016)	p = 0,005; OR = 13,00
Household contact with TB patients	Karminiasih et al. (2016)	AOR = 3,1

Discussion

Upon conducting a literature review of the ten selected articles, several aspects and factors emerged as significant risks for tuberculosis (TB) relapse in patients previously declared cured. The majority of these studies consistently highlighted behavioral aspects as the most influential in causing TB recurrence. Beyond individual behaviors, socioeconomic conditions, healthcare services, biological factors, and the physical environment also notably contributed to TB relapse. Additionally, a study by Sukmaningtyas et al. [20] indicated that TB patient relapse, on average, occurred 17 months after the completion of initial treatment, emphasizing the need for prolonged post-treatment monitoring. This comprehensive review aims to synthesize these findings and provide a multi-faceted understanding of TB relapse drivers within the Indonesian context.

Behavioral Aspects

Behavioral aspects consistently surfaced as the most dominant contributors to TB relapse across the reviewed articles. Among these, smoking habits or exposure to cigarette smoke were identified as a crucial and consistently reported factor, appearing in six of the ten articles [21], [22], [23], [24], [25], [29]. Smoking directly compromises the immune system and damages lung tissue, rendering patients more susceptible to recurrent infections [5], [5.1]. Studies by Ratnawati & Arifin [21] showed a significant association between smoking and TB relapse (p = 0.027), while Jaya & Mediarti [22] reported an odds ratio of 3.2 (p = 0.045), indicating that smokers are 3.2 times more likely to experience relapse. Tumiwa et al. [23] further corroborated this finding with a significant p-value of 0.010. Notably, none of the reviewed studies indicated that smoking did not significantly influenced TB relapse. Furthermore, the descriptive findings by Ulfa et al. [24] in Jambi City showed that the majority of TB relapse patients had a history of smoking, strongly supporting the critical role of smoking in post-treatment recurrence. This consistent evidence underscores that smoking cessation interventions are vital for preventing TB relapse.

Beyond smoking, poor medication adherence emerged as another significant behavioral factor, identified in four articles [23], [25], [27], [29]. Non-adherence prevents the complete eradication of Mycobacterium tuberculosis, often leading to recurrence or even drug resistance [3]. Kusumajaya [25] and Tumiwa et al. [23] both reported highly significant associations ($p = 0.000$), highlighting the critical impact of consistent treatment adherence on preventing relapse. This underscores the urgent need to strengthen Directly Observed Treatment, Short-course (DOTS) programs and enhance direct supervision by healthcare providers and family members [7.1], [7.2]. Furthermore, one study specifically noted the importance of adherence to previous treatment regimens ($p = 0.005$; OR = 13.00) [26], reinforcing that patient behavior during the initial treatment phase profoundly influences future relapse risk. Addressing these behavioral factors through comprehensive patient education and support programs is crucial for improving long-term TB outcomes.

Socioeconomic Aspects

Socioeconomic factors also play a substantial role in TB relapse. Low educational attainment was highlighted in three articles as a contributing factor [21], [22], [25]. Individuals with lower education levels may have limited understanding of the disease, the importance of completing the full treatment course, or the necessity of avoiding risk factors like smoking [3.1]. Kusumajaya [25] found a strong association between education and relapse ($p = 0.000$), while Jaya & Mediarti [22] reported that patients with lower education were 4.2 times more likely to relapse ($p = 0.017$; OR = 4.2). This suggests that educational interventions, tailored to different literacy levels, are fundamental for enhancing health literacy and promoting sustained adherence to TB prevention strategies. Public health campaigns need to consider diverse educational backgrounds to effectively convey critical information about TB management and relapse prevention [3.2].

Furthermore, family support was consistently identified as a significant factor in two studies [27], [28]. Family members can provide crucial oversight of medication intake, offer motivation, and provide attention to lingering symptoms [4.1]. Yunita et al. [27] found a significant relationship between family motivation and TB relapse ($p = 0.001$), a finding echoed by Siburian et al. [28] ($p = 0.01$). This social support is paramount, especially for ensuring the success of long-term therapy [4.2]. Families can serve as an integral part of the DOTS strategy by directly observing medication intake and providing emotional encouragement, thereby mitigating the risk of non-adherence and subsequent relapse [4.3]. Strengthening family involvement through patient and family education programs can significantly bolster treatment outcomes and prevent recurrence.

Healthcare Service Aspects

Healthcare service factors, while not as frequently cited as behavioral aspects, are equally important. Several studies indicated that the setting of treatment, particularly hospital-based care, had a significant relationship with TB relapse. Sukmaningtyas et al. [20] found that hospital treatment acted as a protective factor (HR = 0.81; $p = 0.00$), meaning patients treated in hospitals had a lower risk of relapse compared to those treated elsewhere. This could be attributed to more intensive monitoring, better access to diagnostic tools, and consistent healthcare professional oversight in a hospital setting. This finding suggests that enhancing the quality and accessibility of healthcare services, especially for initial TB treatment, is vital for long-term success.

Moreover, the same study by Sukmaningtyas et al. [20] highlighted that lack of sputum conversion (HR = 0.58; $p = 0.00$) and treatment duration less than 6 months (HR = 0.008) were significantly associated with relapse. These findings emphasize the critical importance of rigorous monitoring of treatment progress, particularly sputum smear microscopy results, to confirm bacterial clearance before declaring a patient cured. Premature cessation of treatment or inadequate duration leaves residual bacteria, paving the way for relapse and drug resistance [8], [9]. Irregular treatment history or inconsistencies in follow-up were also noted in two articles as contributors to recurrence. Therefore, robust patient tracking systems, regular follow-up appointments, and clear protocols for treatment completion are indispensable elements in preventing TB relapse within Indonesia's healthcare system [7.1], [7.2].

Biological / Medical Aspects

Biological and medical aspects, including age, gender, nutritional status, and comorbidities, also contribute to TB relapse, albeit with varying frequencies in the reviewed literature. Kusumajaya [25] showed a significant association between age ($p = 0.001$) and relapse, indicating a higher risk in older age groups. Older individuals may have weakened immune systems or more comorbidities, making them more vulnerable to recurrence [6.3]. However, some studies, like those by Jaya & Mediarti [22] and Sukmaningtyas et al. [20], reported no significant association with age or gender, possibly due to differences in study settings, sample sizes, or measurement methodologies. This discrepancy suggests the need for further research to clarify the precise role of age and gender in TB relapse in diverse Indonesian populations.

Crucially, poor nutritional status and comorbidities, particularly Diabetes Mellitus (DM), were identified as significant risk factors by Karminiasih et al. [29]. The adjusted odds ratio for DM was 9.6, making it one of the highest risk factors identified in this review. DM impairs cellular immunity, increasing susceptibility to TB infection and reactivation, and it can also negatively impact treatment outcomes and increase the risk of relapse [6.1], [6.2]. A poor nutritional status (AOR = 2.8) further compromises the immune system, hindering effective recovery and increasing vulnerability to recurrence [29]. These findings underscore the importance of comprehensive patient assessment, including screening for underlying conditions like diabetes and addressing malnutrition, as part of routine TB management in Indonesia. Integrated care models that address both TB and common comorbidities are essential for minimizing relapse rates [1.2].

Physical Environmental Aspects

Finally, the physical living environment cannot be overlooked as a contributor to TB relapse. Studies highlighted that poor house ventilation, the type of flooring, and the type of house walls, along with household contact with TB patients, exacerbate the risk of recurrence. Karminiasih et al. [29] showed that house ventilation below 10% was significantly associated with relapse (AOR = 3.4; 95% CI 1.27–9.47), and household contact with other TB patients also contributed to the risk (AOR = 3.1). Poor ventilation and crowded living conditions facilitate the airborne transmission of Mycobacterium tuberculosis, making re-infection or exogenous relapse more likely [2.1], [2.2].

Nurwanti & Wahyono [26] further detailed the impact of housing conditions, reporting significant odds ratios for the type of house floor (OR = 11.667; $p = 0.011$) and type of house wall (OR = 13.00; $p = 0.005$). These structural characteristics often reflect socioeconomic status and housing quality, where inadequate materials can lead to damp, unhygienic, and poorly ventilated environments, conducive to bacterial survival and transmission [2.3]. Addressing these environmental determinants through improved housing initiatives, public health education on safe living practices, and targeted interventions for households with active TB cases is crucial for breaking the chain of transmission and reducing relapse rates in Indonesia. This multifaceted approach is consistent with the WHO's End TB Strategy, which emphasizes addressing social and environmental determinants of health [2.2].

IV. CONCLUSION

This comprehensive review highlights that multiple interconnected factors significantly contribute to tuberculosis (TB) recurrence in Indonesia, with behavioral factors—particularly smoking and medication non-adherence—being the most consistent and impactful determinants. Socioeconomic status, including low education levels and limited family support, further exacerbates the risk, while healthcare service quality, treatment duration, and sputum conversion status play crucial roles in preventing relapse. Additionally, biological aspects such as age, comorbidities like diabetes mellitus, and poor nutritional status, alongside environmental factors like inadequate housing ventilation and household contact with TB patients, collectively influence recurrence rates.

Despite these robust findings, the current literature faces limitations such as heterogeneity in study designs, relatively small sample sizes, and potential recall bias, which may affect the generalizability of results. Future research should focus on longitudinal, multicenter studies with larger cohorts to establish causal relationships and evaluate the effectiveness of integrated interventions addressing behavioral,

socioeconomic, and environmental determinants. Furthermore, exploring innovative strategies for enhancing treatment adherence, community engagement, and housing improvements could provide more comprehensive approaches to reducing TB relapse, ultimately supporting Indonesia's goal of TB elimination by 2030.

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