ORIGINAL RESEARCH ARTICLE

Risk Factors for Pulmonary Tuberculosis Transmission Among Prisoner in Correctional Facilities in Lhokseumawe City, Aceh, Indonesia

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ABSTRACT

Background: TB remains a significant public health issue in prisons, facilitating its transmission and affecting both inmates and the wider community. This study aimed to develop a predictive model for TB prevalence and risk factors in prisoners, specifically in class 2A correctional institutions in Lhokseumawe City, Aceh Province, Indonesia.

Methodology: This case-control study included 100 prisoners who were selected through random sampling. Data were gathered through questionnaires and prison medical records. Bivariate analysis and multivariable logistic regression were performed, and p-values ≤ 0.05 set statistically significant.

Results: Medical records revealed 12 inmates with TB. Bivariate analysis identified marital status (odds ratio [OR], 1.2; 95% CI [1.08–1.34]; p=0.017), nutritional status (OR, 3.63; 95% CI [1.05–12.55]; p=0.033), comorbidities (OR, 4.47; 95% CI [1.28-15.56]; p=0.013), and contact with active TB patients (OR, 9.8; 95% CI [5.45-17.63]; p=0.013) as risk factors. Multivariate analysis showed that comorbidities (OR, 5.52; 95% CI [5.45-17.63]; p=0.025) and nutritional status (OR, 4.46; 95% CI [5.45-17.63]; p=0.012) were the most significant risk factors.

Conclusions: Marital status, nutritional status, comorbidities, and contact with patients with active TB were significantly associated with TB incidence of TB among prisoners. Nutritional status and comorbidities were the most significant risk factors.

Keywords: Tuberculosis, Prevalence, Risk Factors, Prisoners

ARTICLE INFO

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INTRODUCTION

The World Health Organization's 2023 Global Report on tuberculosis (TB) indicated that 10.6 million people have contracted TB.[1] TB transmission remains a persistent challenge in Indonesia, affecting both public health and economic stability.[2] In Indonesia, the highest number of TB cases in 2022 and 2023, with over 724,000 new cases by 2022, increasing to 809,000 by 2023.[3] In 2023, the United States Agency International Development reported TB prevalence in Indonesian prisoners to be 2,100-4,400 per 100,000 cases.[4] Prisons are significant reservoirs for TB transmission, with a TB incidence 5-70 times higher than that in the general population. This increased incidence is due to overcrowding, prisoners from high-risk TB groups, comorbid diseases, smoking, and prior contact with patients with TB.[5,6]

Globally, prisoners are at a disproportionately higher risk of contracting TB than the general population, with studies indicating that the incidence rates can be as high as 15 new infections per 100 person-years.[7] This elevated risk is attributed to several interrelated factors, including overcrowding, poor ventilation, inadequate healthcare access, and the high prevalence of comorbid conditions such as HIV.[8,9] The prison environment often exacerbates these conditions, creating a conducive setting for the transmission of Mycobacterium tuberculosis. Epidemiological studies have consistently shown an alarmingly high prevalence of TB in prisons. For instance, a systematic review and meta-analysis revealed that the pooled prevalence of TB among incarcerated individuals is significantly greater than that of the general population, with estimates suggesting that approximately 2.8% of prisoners have active TB.[7]

Factors associated with TB among prisoners include not only the physical conditions of incarceration, but also socioeconomic determinants. Overcrowding is a critical factor as it facilitates close contact among inmates and increases the likelihood of transmission. Moreover, the stigma associated with TB can hinder individuals from seeking timely medical attention, further complicating control efforts.[8] Additionally, poor nutrition and lack of health education contribute to the vulnerability of this population.[10]

Recent studies have highlighted the importance of implementing targeted screening and intervention strategies within prison settings to mitigate the risk of transmission of TB. For example, involving inmates in TB education and detection programs has shown promise in improving case detection rates.[11] Furthermore, the WHO recommends active case finding and preventive measures tailored to the unique challenges of prison environments.[12] Such strategies are essential not only for protecting the health of prisoners but also for preventing spillover effects into the broader community, as TB transmission can extend beyond prison walls.[13]

Prisoners have higher TB rates and worse treatment outcomes than the general population, making them vulnerable to TB infection.[14,15] Prisoners experience disproportionately poor physical and mental health. Prisoners, a highly marginalized and discriminated group, face increased risks of TB, HIV, hepatitis C, sexually transmitted infections, mental illness, and substance use disorders and have poorer health outcomes when ill. These issues stem from complex inequalities, injustices, and social determinants that affect health.[4,16] TB is a major public health concern among prison populations, contributing to its spread and ongoing impact on both this group and the broader community.[6,17]

A preliminary study at the Lhokseumawe City Correctional Institution revealed a 13-fold increase in the number of TB cases between 2022 and 2023. The high incidence of TB in prisons is due to overcrowding, inmates from high-risk TB groups, comorbidities, tobacco use, and a history of contact with patients with TB. However, predictive modelling to assess risk factors for TB has not been conducted in prisons in this area.

This study aimed to investigate the risk factors and develop a predictive model of tuberculosis transmission among prisoners at the Lhokseumawe City Correctional Institution, Aceh Province, Indonesia.

METHODOLOGY

This case-control study was conducted over four months (June to September 2024) at the Correctional Institution Class 2A in Lhokseumawe City, Aceh Province, Indonesia. The Class IIA Lhokseumawe Correctional Institution of the Aceh Ministry of Law and Human Rights Regional Office currently has 602 male prisoners with various criminal offenses. Prisons with an occupancy capacity of only 150 people currently have been occupied with an excess capacity that is four times the normal occupancy capacity.

Collection of inmates' information: The participants were recruited through simple random sampling. A semi-structured questionnaire developed in Bahasa Indonesia was used to collect data from the participants. The questionnaire was based on several previous studies on TB among prisoner.[18–20] However, the questionnaire has not been piloted or validated. All the subjects were examined and questioned by the principal investigator. The principal investigator was a medical doctor (MD) and PhD in public health, with experience in qualitative research.

The inclusion criteria comprised individuals who had been incarcerated for a period exceeding six months and were diagnosed with tuberculosis during their imprisonment. The exclusion criteria included prisoners who were diagnosed with tuberculosis upon admission, patients with severe or terminal illnesses, and those who were unwilling to participate as research subjects.

The questionnaire consisted of five sections: sociodemographic information (age, sex, marital status, educational status, occupation before incarceration, and length of incarceration); health behavioral characteristics (use of illicit drugs, smoking, and contact with patients with active pulmonary tuberculosis inside or outside the prison); health history (previous treatment for active tuberculosis and presence of diabetes mellitus, hypertension, asthma, or other diseases, and medication use); clinical data (blood pressure and BMI); and prison conditions (cell temperature, humidity, lighting, and ventilation).

The cell temperature and humidity were measured using a digital hygrometer. Measurements were conducted three times daily over a one-week period to obtain sufficient data for analyzing the patterns of temperature and humidity fluctuations at the prison. These measurements were recorded in the morning between 7:00 and 8:00 am, midday from 12:00 to 1:00 pm, and late afternoon from 4:00 to 5:00 pm. However, ventilation within cell layouts or prison conditions is inadequate to such an extent that comprehensive assessment is not feasible.

Variables: The dependent variable was tuberculosis prevalence. Tuberculosis diagnosis was obtained from the medical records. Tuberculosis was diagnosed using clinical signs, sputum tests, and X-rays. The independent variables were age, sex, marital status, educational status, nutritional status, contact with active TB inmates, occupation before incarceration, length of imprisonment, length of stay in prison, comorbidities, cigarette smoking, history of illicit drug use, number of prisoners per cell, and prison cell condition.

Statistical analysis: Descriptive statistics are presented as mean and standard deviation (SD). A chi-square test was performed on contingency tables. Bivariate analysis allowed the estimation of crude odds ratios (OR) and 95 % confidence intervals (95 % CI). Variables derived from the results of the bivariate test were subsequently analyzed using a multivariate test, which yielded a p-value < 0.25. Factors independently associated with TB occurrence were analyzed using logistic regression. Logistic regression analysis identified factors independently associated with TB occurrence. Only the variables showing a significant independent association with the dependent variable remained in the final model. For each associated factor, tuberculosis infection in prisoners was calculated using the following formula: $p = 1/(1+e^{-y})$. Results were considered significant when p-values were less than 0.05. All statistical analyses were performed using SPSS version 22 software (IBM Corp., Armonk, New York, USA).

Approval of Institutional Ethical Review Board: Ethical approval was obtained from the Ethics Research Commission of the Faculty of Medicine, Universitas Malikussaleh (No. 21/KEPK/FKUNIMAL-RSUCM/2024; May 14, 2024). All participants provided informed consent and confidentiality was maintained for all collected data.

RESULTS

A total of 100 male prisoners were recruited for the study. The results of the sociodemographic characteristics of the inmates showed that prisoners' ages ranged from 25 to 64 years. Most prisoners (76 %) were first offenders and 52% were sentenced over two years.

Table 1: Sociodemographic characteristics of the prisoners (n = 100)

Characteristics	Participants (%)
TB positive	12 (12.0)
Age group (year)	
16-24	4 (4.0)
25-44	64 (64.0)
≥ 45	32 (32.0)
Educational status	
Low	47 (47.0)
Middle	46 (46.0)
High	7 (7.0)
Occupation	
Student	1 (1.0)
Civil servant	4 (4.0)
Farmer/fisherman	40 (40.0)
Construction worker	8 (8.0)
Driver	5 (5.0)
Self-employed	27 (27.0)
Seller	7 (7.0)
Unemployed	4 (4.0)
Others	4 (4.0)
Marital Status	
Single	29 (29.0)
Married	56 (56.0)
Widower	6 (6.0)
Divorced	9 (9.0)
BMI	
Normal	8 (8.0)
Overweight	17 (17.0)
Obesity grade 1	28 (28.0)
Obesity grade 2	47 (47.0)
Contact with active TB inmates	2 (2.0)
Comorbidities	28 (28.0)
Smoking	80 (80.0)
History of illicit drug used	71 (71.0)
Length of sentences (year)	
≤ 2	48 (48.0)
> 2	52 (52.0)
Number of previous sentences	
> 1	24 (24.0)
First time	76 (76.0)
Number of prisoners per cell	
< 25	31 (31.0)
25-50	47 (47.0)
> 50	22 (22.0)
Humidity of the cells	
≤ 60 %	100 (100.0)
> 60%	0 (0.0)
Temperature of the cells	
≤ 30 °C	0 (0.0)
> 30 °C	100 (100.0)
Lighting of the cells	
< 120 Lux	94 (94.0)
≥ 120 Lux	6 (6.0)

Nearly half of the prisoners (47%) had low educational status, 56% were married, 40% were farmers or fishermen, and 47% were living under the range of 25-50 individuals per cell. Forty-seven prisoners were obese and more than half had good health behaviors regarding cough habits and sputum disposal. Twelve inmates (12.0%) were diagnosed with TB, based on their medical records (Table 1).

Regarding factors associated with tuberculosis among prisoners, the following parameters were considered risk factors for developing TB: marital status (OR, 1.2; 95 % CI [1.08–1.34]); p=0.017), nutritional status (OR, 3.63; 95 % CI [1.05–12.55]; p=0.033), comorbidities (OR 4.47; 95 % CI [1.28-15.56]; p=0.013), and contact with active TB patients (OR, 9.8; 95 % CI [5.45-17.63]; p=0.013) (Table 2).

Table 2: Bivariate analysis showing predictors of TB among prisoners (n=100)

Variable	TB Status		OR (95% CI)	p-value
	Yes (n=12) (%)	No (n=88) (%)		
Age group (year)				
< 45	9 (75)	59 (67)	1.48 (0.37-5.86)	0.747
≥ 45	3 (25)	29 (33)	Ref	
Educational status				
Low	11 (91.7)	82 (93.2)	0.81 (0.09-7.33)	1
High	1 (8.3)	6 (6.8)	Ref	
Marital Status				
Single	0 (0)	29 (33)	1.20 (1.08-1.34)	0.017*
Married/Divorced	12 (100)	59 (67)	Ref	
Nutritional status				
Not Obese	6 (50)	19 (21.6)	3.63 (1.05-12.55)	0.033*
Obese	6 (50)	69 (78.4)	Ref	
Contact with active TB patients	2 (16.7)	0 (0)	9.8 (5.45-17.63)	0.013*
Comorbidities	7 (58.3)	21 (23.9)	4.47 (1.28-15.56)	0.013*
Smoking	10 (83.3)	80 (90.9)	0.50 (0.09-2.69)	0.343
History of illicit drug used	10 (83.3)	61 (69.3)	2.21 (0.45-10.79)	0.5
Length of sentences (year)				
≤ 2	5 (41.7)	43 (48.9)	0.75 (0.22-2.54)	0.64
> 2	7 (58.3)	45 (51.1)	Ref	
Number of previous imprisonments				
>1	1 (8.3)	23 (26.1)	0.26 (0.03-2.10)	0.284
First time	11 (91.7)	65 (73.9)	Ref	
Number of inmates per cell				
> 50	4 (33.3)	18 (20.5)	1.94 (0.53-7.19)	0.456
≤ 50	8 (66.7)	70 (79.5)	Ref	
Cell lighting				
< 120 Lux	11 (91.7)	83 (94.3)	0.66 (0.07-6.21)	0.545
≥ 120 Lux	1 (8.3)	5 (5.7)	Ref	
Cough behaviour				
Poor	2 (16.7)	31 (35.2)	0.37 (0.08-1.79)	0.2
Good	10 (83.3)	57 (64.8)	Ref	
Sputum disposal behaviour				
Poor	2 (16.7)	34 (38.6)	0.32 (0.07-1.54)	0.203
Good	10 (83.3)	54 (61.4)	Ref	

*Statistically significant at $p<0.05$

Table 3: Factors associated with tuberculosis among prisoners using multivariate analysis

Variables	Adjusted OR (95% CI)	Constant	Coefficient	p-value
Nutritional Status (normal and overweight)	4.64 (1.21-17.81)	-0.021	1.535	0.025*
Comorbidities	5.52 (1.45-20.95)		1.708	0.012*

*Statistically significant at $p<0.05$

Multivariate analysis revealed that nutritional status (p = 0.033) and comorbidities (p = 0.013) were significantly associated with TB incidence (Table 3). The strength of the association from strongest to lowest was comorbidities (OR = 5.52) and nutritional status (OR = 4.46). Therefore, the following equation was obtained:

$y = \text{constant} + a_1 \times 1 + a_2 \times 2 + \ldots.. + a_i x_i.$

y = -0,021 + 1,535 (nutritional status) + 1,708 (comorbidities)

The derived equation was applied to predict the probability of tuberculosis infection in incarcerated individuals using the following formula: $p = 1/(1+e^{-y})$. Therefore, for prisoners with normal nutritional status (i.e., not obese) and comorbidities, the probability of tuberculosis can be calculated as follows:

$y = -0,021 + 1,535\ (1) + 1,708\ (1)$
$y = -0,021 + 1,535 + 1,708 = 3,222$

Therefore, the probability of a prisoner having tuberculosis, $p = 1/(1+e^{-y}) = p = 1/(1+2,7^{-3,222}) = 0,96$.

Discussion

A statistically significant association was observed between marital status and tuberculosis infection among prisoners (p=0.017). This observation aligns with that of Mansoori et al. (2024), who demonstrated an association between tuberculosis and marital status.[21] Beza et al also found that married prisoners frequently receive visitation from family members, including spouses and children. Some inmates who participated in the study had a family history of tuberculosis. There is a potential for tuberculosis transmission to prisoners through contact with visiting family members, in addition to interactions with fellow inmates who are also affected by tuberculosis.

The study found a significant association between nutritional status and TB incidence of pulmonary tuberculosis among prisoners (p=0.025). Non-obese prisoners had a 3.63 times higher risk of developing tuberculosis than their obese counterparts. Although no prisoners were classified as malnourished or undernourished, non-obese tuberculosis patients had a 78.4% higher probability of contracting the disease than obese prisoners, who reported that nutritional status increases the incidence of pulmonary tuberculosis, whereas tuberculosis affects the nutritional status of those affected.[22] Nutritional status is crucial for the body's defense against tuberculosis infection, as poor nutrition compromises the immune response. The relationship between tuberculosis and malnutrition is bidirectional; malnutrition increases the risk of tuberculosis, and tuberculosis-induced malnutrition can reduce treatment efficacy and worsen prognosis.[23]

Poor nutritional conditions in prisons are often linked to overcrowding and inadequate healthcare services, which can lead to increased susceptibility to infectious diseases like TB.[10,24] The findings resonate with the observations of Filho et al., who noted that the lack of effective TB control measures, including proper nutrition, significantly contributes to the TB epidemic in prisons.[10] These findings are consistent with those of a previous study in the Central Prison of Mbuji-Mayi, Democratic Republic of Congo, which found malnutrition to be a risk factor for TB in prisoners. Individuals incarcerated for over six months, especially those with TB, HIV, or intestinal infections, face critical nutritional issues.[20] Moreover, Bilmumad et al. (2022) revealed that prisoners in Southern Thailand who were underweight had higher odds of having pulmonary TB.[18] Although underweight and malnourishment were not observed in the present study, nutritional deficiencies were common among the prisoners. A study in Fiche City, Ethiopia, also found significant malnutrition among adult prisoners, with one in five inmates malnourished.[25] As no malnourished tuberculosis patients were found in the Lhokseumawe City Prison, the administered therapy likely resulted in a favorable prognosis.

A history of contact with tuberculosis inmates was significantly associated with tuberculosis infection in prisoners (p=0.013). Prisoners who had a history of contact with TB patients exhibited a 9.8-fold increased risk of contracting tuberculosis compared to prisoners without such contact history. Consequently, the probability of tuberculosis infection in prisoners with a history of contact with TB patients was 90.7%. The high rates of TB transmission in prisons are often attributed to close quarters and the high likelihood of exposure to infected individuals.[26] The conditions in prisons, characterized by high-density occupancy, facilitate contact between inmates, including those with TB. Despite being housed in separate detention cells, prisoners interact with each other during religious, mealtime, and recreational activities. This interaction persists throughout the incarceration period. Prisons represent an environment conducive to M. tuberculosis transmission, featuring overcrowded spaces, inadequate ventilation, and high prisoner turnover rates.[27] The frequent transfer of inmates between correctional facilities establishes a network of prison contacts that may facilitate the transmission of M. tuberculosis and potentially increase the risk of infection in the general population.[28]

The presence of comorbidities in prisoners was significantly associated with tuberculosis incidence (OR, 4.47; 95% CI 1.28-15.56; p=0.013). Individuals with comorbidities had a 4.47-fold higher risk of developing tuberculosis. Comorbidities were more prevalent among prisoners, with affected individuals being 81.7% more likely to develop tuberculosis. The most common comorbidities were diabetes mellitus and hypertension. Our findings are consistent with Nunemo et al. (2023), who reported a 9.33-fold increased likelihood of tuberculosis infection among individuals with comorbidities.[29] Comorbidities were also found to be a significant risk factor), indicating that prisoners with pre-existing health conditions are at a heightened risk for developing TB. This is consistent with previous studies that showed a strong correlation between comorbidities, such as HIV infection and diabetes, and increased TB incidence. The presence of comorbidities can complicate the clinical management of TB and lead to poorer treatment outcomes.[30]

Diabetes mellitus (DM) is a chronic disease that compromises the immune system and increases susceptibility to tuberculosis. Elevated blood glucose levels in patients with DM further increases the risk of TB. Active tuberculosis can worsen hyperglycemia and increase the risk of sepsis in patients with DM.[31] Inmates exhibited comorbidities such as diabetes mellitus, hypertension, and asthma, with diabetes being the most common. Diabetes increases susceptibility to TB through multiple factors and mecha-

nisms. As a chronic condition, it weakens the immune system and hinders the control of infection. It disrupts cytokine production and cellular immunity, impairing neutrophils, macrophages, and natural killer cells. Diabetes also affects complement system and antibody production. A previous study showed that individuals with diabetes mellitus are at high risk of TB infection.[32] Hypertension was the second most common comorbidity among the incarcerated prisoners. Hypertension is a major risk factor for cardiovascular diseases, although no direct causal link exists between hypertension and tuberculosis. Previous studies reported an increased risk of cardiovascular events in patients with respiratory infections. The prevalence of hypertension in patients with tuberculosis ranges from 0.7% to 38.3%, and patients with high blood pressure at the start of tuberculosis treatment have higher mortality rates.[33] Poor environmental conditions in correctional facilities accelerate the proliferation of Mycobacterium tuberculosis. Although ventilation and cell conditions were not quantitatively assessed, overcrowding in correctional facilities likely contributed to TB transmission observed in our study.

Limitations

This study has several limitations, including the small number of TB samples and diagnosis of TB based on secondary data from medical records. Further studies should employ a longitudinal design to clarify the associations between risk factors and TB among prisoners more comprehensively.

Conclusion

In this study, marital status, nutritional status, comorbidities, and contact with active TB inmates were significantly associated with the TB incidence in this prison population. Nutritional status and comorbidities were the most significant risk factors. Recommendations to address TB risk factors among prisoners in Lhokseumawe city prison include improving nutrition, enhancing screening practices, and addressing social determinants of health. Regular screening protocols including entry-level and periodic assessments should be implemented to facilitate early detection and treatment. Furthermore, comprehensive health assessments are conducted to identify inmates with preexisting conditions and provide appropriate medical care to manage these comorbidities.

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Authors' Contributions: CK: Study conception, Study design, Data analysis and interpretation, Manuscript preparation; **MM and AM:** Data collection, Data analysis and interpretation, Manuscript preparation; **SW:** Study design, Data analysis and interpretation, Manuscript preparation; **PSL and MI:** Data collection

Availability of Data: The data that support the findings of this study are available from the corresponding author upon reasonable request.

No use of generative AI tools: During the preparation of this study, the author(s) did not use Generative AI and AI-assisted technologies.

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