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ANALYSIS OF FACTORS INCLUDING PULMONARY TUBERCULOSIS IN DIABETES MELLITUS PATIENTS

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ABSTRACT
The syndemic between Pulmonary Tuberculosis (TB) and Diabetes Mellitus (DM) is a public health challenge because DM can weaken the immune system and poor glycemic control facilitates infection by Mycobacterium tuberculosis. As the prevalence of DM in Indonesia increases, identifying risk factors that contribute to the incidence of TB in DM patients becomes important. This study aims to analyze the relationship between nutritional status, glycemic control, income level, education level, and access to health services with the incidence of pulmonary TB in DM patients. The study used an observational analytical design with a cross-sectional approach conducted at Tgk. Chik Ditiro Sigli Regional Hospital from June–September 2025 with a sample of 277 DM patients selected through purposive sampling. Data were collected using mixed methods, namely secondary data from medical records for TB status, nutritional status, and glycemic control and primary data through questionnaires for income and access to health services using the Cronbach's Alpha method with a value of ⩾0.70.The results showed that the majority of respondents did not have pulmonary TB (75.09%), but the majority had poor nutritional status (68.95%) and most had controlled glycemic control (71.12%). In addition, more than half of respondents had incomes below the Provincial Minimum Wage (56.68%) and about half had poor access to health services (50.54%). The analysis showed a significant association between poor nutritional status (AOR=2.5; 95% CI=1.17–5.39), uncontrolled glycemic control (AOR=4.5; 95% CI=2.43–8.68), income <UMP (AOR=1.9; 95% CI=1.02–3.85), and poor access to health services (AOR=3.2; 95% CI=1.65–6.30) with the incidence of pulmonary TB in DM patients,

Keywords: diabetes mellitus; glycemic control; healthcare access; nutritional status; pulmonary tuberculosis

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INTRODUCTION

Pulmonary tuberculosis is a major health problem worldwide. The World Health Organization estimates that there were approximately 10 million new cases of tuberculosis worldwide in 2020, resulting in approximately 1.5 million deaths (WHO, 2021). Tuberculosis is currently a serious and highly prevalent public health problem in Indonesia. Indonesia even has the second-highest number of tuberculosis cases in the world after India, with an estimated annual incidence of over 1 million new cases (WHO, 2023). Furthermore, the incidence of diabetes mellitus continues to increase in line with changes in lifestyle and dietary patterns. This disease not only increases the risk of metabolic complications but also increases susceptibility to various infectious diseases, including tuberculosis (IDF, 2021).

Diabetes mellitus is a metabolic condition characterized by hyperglycemia due to impaired insulin secretion, insulin action, or both. This condition is a significant factor that can increase the risk of pulmonary tuberculosis in diabetic patients (ADA, 2020). A meta-analysis showed that individuals with diabetes have a three-fold higher risk of developing pulmonary tuberculosis compared to individuals without diabetes (Bae, 2019). Hyperglycemia can affect the immune system, facilitating infection and the growth of Mycobacterium tuberculosis. Therefore, people with diabetes are at a higher risk of developing tuberculosis (Restrepo, 2008). Several studies also show that people with diabetes have a two- to three-fold higher risk of tuberculosis infection compared to individuals

without diabetes (Kumar, 2015). This is related to the impact of diabetes on the immune system, which reduces the body's ability to fight infections, including tuberculosis. Furthermore, hyperglycemia can worsen infections and slow the healing process, making diabetic patients more susceptible to pulmonary tuberculosis (Kumar, 2021).

Tuberculosis (TB) and diabetes mellitus (DM) are closely related, with TB significantly increasing the risk of developing diabetes by approximately three times and often revealing previously undiagnosed cases of diabetes. Globally, the prevalence of TB in diabetes patients is high, averaging over 15%, but shows wide variation across regions, ranging from 1.8% to over 45%, particularly in low-income countries (Alturki et al., 2023).

Statistics show that the incidence of diabetes is also increasing in Indonesia. According to the 2018 Basic Health Research (Riskesdas) data, approximately 10.9% of adults in Indonesia have diabetes. This increasing diabetes rate has the potential to increase the risk of tuberculosis. Data from the Indonesian Ministry of Health indicates that in 2020 the incidence of tuberculosis in Indonesia reached approximately 299 cases per 100,000 population (Kemenkes RI, 2021).

A study conducted in Jakarta found that approximately 30% of hospitalized tuberculosis patients also had diabetes mellitus (Alisjahbana & Bae, 2018). These findings suggest a strong link between the two diseases, and further research is needed to understand the underlying mechanisms. Biologically, immunological mechanisms play a key role in increasing the risk of tuberculosis in patients with diabetes mellitus. Diabetes can cause immune system dysfunction, increasing the patient's susceptibility to infections, including tuberculosis. Research by Restrepo (2008) shows that hyperglycemia can impair the function of macrophages, the key cells in the immune response to Mycobacterium tuberculosis. This decreased function can facilitate bacterial growth and lead to a poorer clinical prognosis.

In addition to biological factors, social and economic factors also influence the interaction between tuberculosis and diabetes. Access to quality healthcare remains limited in many developing countries, including Indonesia, so diabetes patients often do not receive optimal care. This condition can worsen patient health and increase the risk of tuberculosis infection. Data from the Indonesian Ministry of Health shows that diabetes patients who do not receive appropriate treatment have a higher risk of developing tuberculosis, especially in rural areas (Indonesian Ministry of Health, 2020).

Furthermore, other studies have shown that irregular diabetes therapy can also increase the risk of tuberculosis. Patients who do not adhere to their diabetes medication are 1.5 times more likely to become infected with tuberculosis compared to patients who take their medication regularly (Menzies, 2016). This demonstrates the importance of good diabetes management in tuberculosis prevention efforts. Another study conducted in China by Wang (2017) found that tuberculosis patients who also had diabetes had a longer recovery time and a poorer response to tuberculosis therapy. These results emphasize the importance of an interdisciplinary approach in managing patients with diabetes and tuberculosis simultaneously.

Previous research also indicates that various factors contribute to the high incidence of pulmonary tuberculosis in patients with diabetes mellitus. These factors include immunological factors, poor diabetes management, and environmental conditions. All of these factors need to be considered in tuberculosis prevention and treatment efforts in diabetic patients (O'Grady, 2019).

Although various studies have been conducted to examine the relationship between diabetes and tuberculosis, previous research remains limited. Some studies have focused on only one aspect of the relationship, such as the prevalence of tuberculosis in diabetic patients, without considering other factors that may play a role, such as age, gender, and nutritional status (Lönnroth & Harries,

2010). The literature review also revealed research gaps that require further study to gain a more comprehensive understanding of the relationship between diabetes and tuberculosis. Research by Sultana et al. (2020) showed that poor glucose control is associated with an increased risk of tuberculosis in diabetic patients.

The relationship between tuberculosis and diabetes is crucial to examine locally, as various factors such as nutritional status, education level, medication adherence, glycemic control, and socioeconomic conditions can influence the incidence of tuberculosis in diabetic patients (Alisjahbana et al., 2007). In Aceh Province, particularly in Pidie Regency, tuberculosis and diabetes cases show a worrying trend. At Tgk Chik Ditiro Regional Hospital in Sigli, a regional referral hospital, an increase in the number of diabetes and tuberculosis patients has been recorded in recent years. However, there is limited research specifically examining the factors causing tuberculosis in diabetic patients in the region. At this hospital, comprehensive data identifying the specific causes of pulmonary tuberculosis in diabetic patients is also not yet available. These data limitations make it difficult to develop evidence-based interventions that are appropriate to the local policy context. Therefore, research is needed to identify factors associated with the incidence of pulmonary tuberculosis in patients with diabetes mellitus in the region. The aim of this study was to identify the relationship between nutritional status, glycemic control, income level, education level, and access to health services on the incidence of pulmonary tuberculosis (TB) in patients with diabetes mellitus (DM).

METHOD

The research design used was quantitative analytical with a cross-sectional approach. This study was conducted at the outpatient clinic of Tgk Chik Ditiro Sigli Regional Hospital, Pidie Regency. The study population consisted of all outpatients with diabetes mellitus who received treatment at the outpatient clinic during the study period. Based on data from medical records, there were approximately 897 patients with diabetes mellitus registered for treatment at the health facility. A sample of 277 patients was selected using consecutive sampling techniques, including all diabetes patients who met the inclusion and exclusion criteria during the study period at Tgk Chik Ditiro Sigli Regional Hospital. The data collection technique in this study was carried out through primary and secondary data. Primary data was obtained from structured interviews using questionnaires, such as variables, while secondary data came from medical records and health reports. The research instruments, in the form of questionnaires and observation sheets, were first tested for validity using the Cronbach’ s Alpha method with a value of ≥0.70. Data analysis used the chi-square test. Multivariate analysis using logistic regression was performed using STATA.

RESULT

Table 1.
Respondent Characteristics

Characteristics	f	%
Respondent Age		
< 20 years	8	2.89
20-35 years	93	33.57
> 35 years	176	63.54
Gender		
Man	137	49.46
Woman	140	50.54
Employment Status		
Work	195	70.40
Students	25	9.03
Retired	20	7.22
Doesn't work	37	13.36

Table 1 shows the demographic characteristics of respondents, indicating that the majority of respondents are in the adult age group, where 63.54% are aged over 35 years. The productive age group of 20-35 years follows with a portion of 33.57%, while respondents aged under 20 years are a

minority group with only 2.89%. In terms of gender, the distribution of respondents shows an almost balanced composition, with female participation (50.54%) slightly higher than male (49.46%). Meanwhile, the employment status profile is significantly dominated by employed respondents, covering 70.40% of the total sample. The next largest group is those who are unemployed (13.36%), followed by students (9.03%), and retirees (7.22%) as the group with the lowest frequency.

Table 2.
Analysis Univariate

Characteristics	f	%
Pulmonary TB		
Positive	69	24.91
Negative	208	75.09
Nutritional status		
Malnutrition	191	68.95
Good Nutrition	86	31.05
Glycemic Control		
Not controlled	80	28.88
Controlled	197	71.12
Income Level		
< UMP	157	56.68
≥ UMP	120	43.32
Level of education		
Basic/Low	67	24.19
Intermediate	132	47.65
Tall	78	28.16
Access to Health Services		
Not good	140	50.54
Good	137	49.46

Table 2 shows that the health profile of respondents shows that the majority do not suffer from Pulmonary TB (75.09%) and have a controlled glycemic condition (71.12%). However, in terms of nutritional status, most respondents were identified as experiencing malnutrition (68.95%). From a socioeconomic perspective, more than half of respondents have an income level below the Minimum Wage (UMP) (56.68%), with an educational profile dominated by Secondary Education graduates (47.65%), followed by College graduates (28.16%) and Primary/Low Education (24.19%). Finally, the aspect of access to health services shows an almost balanced distribution, where respondents with Poor access (50.54%) are slightly more numerous than those with Good access (49.46%).

Table 3 shows that the nutritional status variable shows a significant relationship with the incidence of pulmonary TB, where malnourished respondents are at 2.6 times higher risk of experiencing pulmonary TB compared to respondents with good nutrition (p = 0.006; OR = 2.6; 95% CI: 1.32–5.19). Furthermore, the glycemic control variable is also significantly related, with the result that patients with uncontrolled blood sugar have a 5.7 times greater risk of suffering from pulmonary TB 54 CS Scanned with CamScanner (p = 0.0001; OR = 5.7; 95% CI: 3.21–10.4). In the income level variable, a 2.71 times greater risk was found in the income group below the UMP (p = 0.001; OR = 2.71; 95% CI: 1.49–4.97). The variable of access to health services also showed a significant relationship, where respondents with poor access had a 4.6 times higher risk (p=0.0001; OR=4.6; 95% CI: 2.47–8.59). In contrast, the variable of education level did not show a significant relationship with the incidence of pulmonary TB, both in the primary education category (p=0.375; 95% CI: 0.64–3.13) and secondary (p=0.156; 95% CI: 0.82–3.22). The analysis results showed that the age variable had an Odds Ratio (OR) value of 1.07 (95% CI: 0.65–1.78) with a p value of 0.769. This indicates that there is no statistically significant relationship between age and the incidence of pulmonary tuberculosis in the study respondents. Although the OR value >1 indicates a tendency for an increased risk of 7% in certain age groups, the confidence interval exceeding 1 and the p value greater than 0.05 indicate that age is not a significant risk factor in this

bivariate analysis. Thus, in the study population, the incidence of pulmonary tuberculosis is not significantly influenced by differences in the age of the respondents.

Table 3.
Analysis Bivariate

Variables	Pulmonary TB				*OR*	*95%CI*	*P-Value*
	Positive		Negative				
	n	%	n	%			
Nutritional status							
Malnutrition	57	29.84	134	70.16	2.6	1.32-5.19	0.006
Good Nutrition	12	13.95	74	86.05			
Glycemic Control							
Not controlled	40	14.72	40	85.28	5.7	3.21-10.4	0.0001
Controlled	29	24.91	168	75.09			
Income Level							
< UMP	51	32.48	106	67.52	2.71	1.49-4.97	0.001
≥ UMP	18	15,00	102	85.00			
Education Level							
Basic/Low	17	25.37	50	74.63	1.4	0.64-3.13	0.375
Secondary	37	28.03	95	71.97	1.6	0.82-3.22	0.156
High	15	19.23	63	80.77			
Access to Health Services							
Not good	53	37.86	87	62.14			
Good	16	11.68	121	88.32	4.6	2.47-8.59	0.0001
Respondent Age							
< 20 years	1	12.50	7	87.50	1.07	0.65-1.78	0.769
20-35 years	24	25.81	69	74.19			
> 35 years	44	25.00	132	75.00			
Gender							
Man	37	27.01	100	72.99	0.8	0.46-1.38	0.425
Woman	32	22.86	108	77.14			
Employment Status							
Work	53	27.18	142	72.82	1.1	0.87-1.49	0.317
Students	4	16.00	21	84.00			
Retired	4	20.00	16	80.00			
Doesn't work	8	21.62	29	78.38			

Table 3 shows that the gender variable shows an OR value of 0.80 (95% CI: 0.46-1.38) with p = 0.425. This value indicates that there is no statistically significant relationship between gender and the incidence of pulmonary TB. An OR value of 0.05 indicates that the difference is not statistically significant. Therefore, gender is not a determinant of the incidence of pulmonary TB in the bivariate analysis of this study. Table 3 shows that the employment status variable shows that of the total of 277 respondents, the majority of respondents were in the working category, namely 195 people (100%), with the proportion of incidents in this group being 55 CS Scanned with CamScanner of 27.18% (53 people) and those who did not experience incidents amounting to 72.82% (142 people). The results of the logistic regression test for employment status showed a value (OR = 1.1; 95% CI: 0.87–1.49; p value = 0.317). Since the p value > 0.05 and the CI range includes the number 1, it can be concluded that there is no statistically significant relationship between employment status and the incidence of the dependent variable in this study. Although the employed group had a slightly higher proportion of incidents than the other groups, the difference was not statistically significant. Therefore, the employment status variable in this bivariate analysis was not proven to be a factor related to the incidence of pulmonary TB in the study.

Table 4 presents the final results of multivariate modeling using logistic regression. This model has a Pseudo R^2 value of 0.2092, indicating that the variables included in the model are able to explain 20.92% of the variation in the incidence of pulmonary TB in diabetes mellitus patients. Based on the Adjusted Odds Ratio (AOR) value, glycemic control was identified as the most dominant determinant factor. Patients with poor glycemic control had a 4.7 times greater risk of developing pulmonary TB compared to patients with controlled glycemic control after adjusting for variables

such as nutritional status, income, education, and access to health services (p=0.0001; AOR=4.7; 95% CI: 2.45–9.02). The next significant factor was access to health services. Patients with poor access to health services had a 3.2 times higher risk of developing pulmonary TB compared to patients with good access to health services after controlling for other variables in the model (p=0.001; AOR=3.2; 95% CI: 1.62–6.30).

Table 4.
Analysis Multivariate

Pulmonary TB	AOR	95% CI Lower-Upper	P
Malnutrition	2.3	1.06-5.09	0.034
Uncontrolled Glycemic	4.7	2.45-9.02	0.0001
Income Level < UMP	2.2	1.03-5.05	0.040
Secondary Education	1.0	0.42-2.37	0.990
Primary/Elementary Education	0.6	0.22-1.90	0.437
Access to health services not good	3.2	1.62-6.30	0.001
Age	1.1	0.60-2.08	0.71
Gender	0.9	0.49-1.78	0.84
Employment Status	1.1	0.87-1.63	0.25

In addition, nutritional status and income level were also shown to have an independent effect on the incidence of pulmonary TB. Patients experiencing malnutrition had a risk of approximately 2.3 times greater to experience pulmonary TB compared to patients with normal nutritional status (p = 0.034; AOR = 2.4; 95% CI: 1.06–5.09). Meanwhile, patients with income levels below the Provincial Minimum Wage (UMP) had a 2.2 times greater risk of experiencing pulmonary TB compared to the group with higher income (p = 0.040; AOR = 2.2; 95% CI: 1.03–5.05). In contrast, education level did not show a statistically significant relationship after adjustment for other variables in the model, both at the secondary education level (p = 0.990; 95% CI: 0.42–2.37) and primary or lower education (p = 0.437; 95% CI: 0.22–1.90). Similarly, the variables age, gender, and employment status also did not show a statistically significant relationship in the full model (p>0.05). Therefore, a stepwise regression approach was conducted with variable selection criteria (pr<0.05) to obtain the most parsimonious model while retaining variables that truly contributed significantly.

Table 5.
Analysis Multivariate (Stepwise)

Pulmonary TB	AOR	95% CI Lower-Upper	P
Malnutrition	2.5	1.17-5.39	0.018
Uncontrolled Glycemic	4.5	2.43-8.68	0.0001
Income Level < UMP	1.9	1.02-3.85	0.043
Access to health service not good	3.2	1.65-6.30	0.001

The results of the multivariate analysis using the stepwise approach in Table 5.4.1 produced a more concise and efficient final prediction model, which was able to explain 20.18% of the variation in the incidence of pulmonary tuberculosis (Pseudo R^2 = 0.2018). This procedure identified four significant independent risk factors, namely poor glycemic control as the most dominant predictor (AOR = 4.5), followed by poor access to health services (AOR = 3.2), malnutrition nutritional status (AOR = 2.5), and income levels below the minimum wage (AOR = 1.9). In this model, the education level variable was automatically excluded because it did not provide a statistically significant contribution. These findings indicate that a combination of clinical factors, accessibility of health services, and socioeconomic conditions are the best predictors in explaining the risk of pulmonary tuberculosis in patients with diabetes mellitus.

The final model's pseudo-R^2 value of 0.2018 indicates that approximately 20% of the variation in pulmonary TB incidence in diabetes mellitus patients can be explained by the variables included in the model. While this value is not particularly high, it is still considered quite good in socio-biomedical epidemiology research, given that tuberculosis incidence is influenced by various complex factors that cannot all be incorporated into the analysis model.

DISCUSSION

This study aims to identify the relationship between nutritional status, glycemic control, income level, education level, and access to health services with the incidence of pulmonary tuberculosis in diabetes mellitus (DM) patients at Tgk Chik Ditiro Sigli Regional Hospital. This study involved 277 DM patients who met the inclusion criteria. The initial distribution showed that the majority of respondents did not suffer from pulmonary tuberculosis (75.09%), most had controlled glycemic control (71.12%), but the proportion of respondents with malnutrition nutritional status was relatively high at 68.95%. In addition, more than half of respondents had an income level below the Provincial Minimum Wage (UMP) at 56.68%. These descriptive findings provide an initial picture that although most DM patients have relatively good glycemic control, there are still socioeconomic factors and nutritional status that have the potential to increase the risk of pulmonary tuberculosis.

The results of bivariate analysis using simple logistic regression showed a significant relationship between uncontrolled glycemic control, poor access to health services, income below the minimum wage, and malnutrition with the incidence of pulmonary TB. The highest odds ratio (OR) value in the bivariate analysis was found in the uncontrolled glycemic control variable with an OR value of around 5.7 (95% CI: 3.21–10.4; $p<0.0001$), which indicates that DM patients with poor glycemic control have a much higher risk of developing pulmonary TB compared to patients with good glycemic control. Meanwhile, the variables of age, gender, and employment status did not show a statistically significant relationship with the incidence of pulmonary TB ($p>0.05$). Therefore, these three variables did not meet the criteria as risk factors in the initial analysis, but were still considered as control variables (confounders) in the multivariate analysis based on theoretical and epidemiological considerations.

Multivariate logistic regression analysis showed that several factors remained statistically significant with the incidence of pulmonary TB in the study respondents. The initial model included variables such as nutritional status, glycemic control, income level, education level, access to health services, age, and gender. After multivariate adjustment, four variables remained significantly associated with increased risk of pulmonary TB: poor glycemic control (AOR≈4.7), poor access to health services (AOR≈3.2), malnutrition (AOR≈2.3), and income below the minimum wage (AOR≈ 2.2). Meanwhile, education level did not show a statistically significant association in the model.

Although age and gender did not show a significant association in the bivariate analysis ($p>0.05$), these two variables were still included in the initial multivariate model based on theoretical and epidemiological considerations. In epidemiological studies of tuberculosis and diabetes mellitus, age and gender are classic determinants that have the potential to act as confounders. However, after multivariate analysis, these two variables and the employment status variable did not show a significant influence and did not substantially change the estimated odds ratio of the main variable. Therefore, through a more parsimonious modeling approach using the stepwise regression method , these variables were eliminated from the final model. These results indicate that in this study population, age, gender, and employment status are not significant confounders in the relationship between biological and social factors and the incidence of pulmonary tuberculosis.

The final multivariate model was able to explain approximately 20% of the variation in pulmonary TB incidence (Pseudo $R^2 \approx 0.2018$). This value indicates that the combination of clinical factors, especially glycemic control, along with healthcare accessibility and socioeconomic determinants contribute significantly to explaining the risk of pulmonary TB incidence in DM patients. However, this value also indicates that there are still other factors outside the model that may play a role in the incidence of pulmonary TB, such as environmental factors, living conditions, housing density, other comorbidities, smoking habits, and health behavior factors not measured in this study.

The findings of this study confirm that TB incidence in DM patients is influenced not only by clinical factors such as glycemic control and nutritional status, but also by social determinants such as economic conditions and access to healthcare. The simultaneous interaction of these biological and social factors suggests a syndemic pattern, where two chronic diseases interact in the context of social inequality and contribute to poorer health outcomes. Therefore, TB control efforts in DM patients cannot focus solely on pharmacological therapy but require a comprehensive approach that includes socioeconomic interventions and strengthening the primary healthcare system.

The Relationship between Nutritional Status and the Incidence of Pulmonary TB in DM Patients

The results of the study showed a significant relationship between nutritional status and the incidence of pulmonary TB in DM patients. Bivariately, DM patients with poor nutritional status or malnutrition had approximately 2.6 times greater odds of experiencing pulmonary TB compared to patients with good nutritional status (OR=2.6; 95% CI: 1.32–5.19; p=0.006). This relationship remained consistent in multivariate analysis, where malnutrition nutritional status remained an independently associated variable (AOR≈2.5; p=0.018) after being controlled by other variables such as glycemic control, access to health services, and income level. These findings indicate that nutritional status is one of the main risk factors correlated with the incidence of pulmonary TB in diabetes mellitus patients.

Biologically, the relationship between malnutrition and TB incidence can be explained through the mechanism of immune system impairment. Malnutrition, particularly energy-protein deficits, is associated with decreased macrophage function and CD4 and CD8 T cell responses, which play a crucial role in eliminating Mycobacterium tuberculosis . In DM patients, malnutrition can exacerbate existing immune dysfunction due to chronic hyperglycemia, thereby increasing susceptibility to TB infection. Previous studies have also shown a similar relationship, with individuals with a low body mass index (BMI) having a higher risk of developing tuberculosis compared to individuals with normal nutritional status.

The findings of this study align with various epidemiological studies showing that poor nutritional status is a significant risk factor for TB. Several studies have reported that individuals with a low body mass index (BMI) have a significantly higher risk of developing tuberculosis compared to individuals with a normal weight. In fact, several studies have shown that each unit increase in BMI is associated with a significant reduction in TB risk. Thus, these results underscore the importance of nutritional intervention as an integral part of the management of patients with diabetes mellitus to reduce susceptibility to tuberculosis infection.

The Relationship Between Glycemic Control and the Incidence of Pulmonary TB in DM Patients

The analysis results showed that poor glycemic control was the most dominant risk factor in this study. Patients with uncontrolled blood sugar had a 5.7 times higher risk of developing pulmonary TB compared to controlled patients in bivariate analysis (OR=5.7; 95% CI: 3.21-10.4; p<0.0001). In multivariate modeling, this variable consistently became the strongest independent predictor (AOR=4.5; p<0.0001) and provided the largest contribution to the model's predictive value (Pseudo R2), which confirms that metabolic factors play a major role in the pathogenesis of TB in DM patients.

The pathophysiological mechanisms underlying these findings include the impact of chronic hyperglycemia on phagocytic function (neutrophil chemotaxis and macrophage phagocytosis) and cellular immune responses (Elsa et al., 2025). Increased glucose levels in pulmonary secretions are also thought to facilitate bacterial growth, while microvascular complications may alter lung tissue homeostasis and local inflammatory responses (Yapislar & Gurler, 2024). The magnitude of the risk found in this study is consistent with the research of Antonio-Arques et al. (2022) in 8,004 patients,

which showed a dose-response relationship: the worse the glycemic control (HbA1c ≥ 9%), the higher the risk of TB (Adjusted HR=2.82). The importance of glycemic control is also emphasized by the meta-analysis of Zhao et al. (2024), which showed that optimal glycemic control can significantly improve TB treatment outcomes (RR 1.13) and accelerate sputum conversion.

Although the DM-TB syndemic is known to increase the risk of active TB by up to threefold, van Crevel & Critchley (2021) highlighted a research gap where TB prevention strategies in the DM population are often overlooked. The clinical implication is the integration of TB screening into DM treatment services. The findings of this study fill this gap by confirming that optimizing diagnosis and glycemic control should be a top public health priority to reduce the burden of TB in DM patients.

The Relationship Between Income Level and the Incidence of Pulmonary TB in DM Patients

This study identified economic-based health disparities, where patients with incomes below the Provincial Minimum Wage (UMP) were 2.7 times more likely to suffer from Pulmonary TB compared to those with incomes below the UMP (OR=2.7; 95% CI: 1.49-4.97; p=0.001). Although the strength of the association slightly decreased after controlling for clinical variables in multivariate analysis, low income remained a significant independent risk factor (AOR=1.9; p=0.043). Researchers assume that low income reflects limited purchasing power for nutritious food, the ability to pay for transportation and health costs, residential density that facilitates transmission, and limited access to prevention and early diagnosis services, all factors associated with increasing the risk of active TB in DM patients.

In line with these findings, research (Maharani et al., 2022) also identified family income as a strong predictor (p<0.001). The study reported that respondents with incomes below the regional minimum wage were 5.301 times more likely (OR=5.301; 95% CI: 2.210-12.665) to suffer from pulmonary TB compared to respondents with incomes above the minimum wage. This finding is also supported by research (Farrah & Akbar, 2025) which reported that low income significantly increases the risk of TB (p=0.015). The study found that individuals with low incomes were 6.923 times more likely (OR=6.923; 95% CI: 1.285-37.287) to suffer from TB compared to those with higher incomes. Income below the minimum wage (UMP) was an independent risk factor for pulmonary TB in DM patients in this study; interventions that strengthen social security and eliminate financial barriers (subsidies, free screening, links with welfare programs) are recommended to reduce the risk of TB in low-income groups.

The Relationship Between Education Level and the Incidence of Pulmonary TB in DM Patients

The distribution of education in the sample showed a majority of high school graduates (47.65%), followed by college (28.16%) and elementary/low school (24.19%). Initial bivariate analysis may have indicated differences in TB prevalence across educational levels, but the final results showed that education level was not significantly associated with pulmonary TB incidence in the multivariate model. The lack of a relationship between TB education level and pulmonary incidence in this study can be explained through a health literacy perspective. Formal education often only reflects functional literacy skills, but does not guarantee critical health literacy related to managing the DM-TB syndemic (Abel & Benkert, 2022). A patient with a high level of education may not necessarily have an adequate understanding of the risks of decreased immunity due to diabetes.

Furthermore, these findings support the materialist perspective on the social determinants of health of Skalická et al. (2009), where tangible material factors such as income level and physical access to health services (both of which were found to be significantly associated in this study) have a more direct (proximal) impact on the risk of infection than social status or education (distal). Higher education qualifications do not can mitigate the risk of TB if the patient experiences economic constraints in purchasing quality nutritional intake or faces structural barriers in accessing health

services. These results support the research of Nuraisyah et al. (2024), which also reported no significant association between education and TB in DM patients. Although Nugrahaeni et al. (2025) found an association in a different population, the data in this study further supports that clinical factors and accessibility are more significantly related than educational status alone. These results confirm that health interventions should not rely on educational strata, but rather focus on factors that have been shown to be significantly related, such as access to services and economic conditions.

The Relationship Between Access to Health Services and the Incidence of Pulmonary TB in DM Patients

Access to health services was identified as having a highly significant association with the incidence of pulmonary TB. Patients with poor access to services were 4.6 times more likely to develop pulmonary TB (OR=4.6; 95% CI: 2.47-8.59; p<0.0001). This association remained consistent and strong in multivariate analysis (AOR=3.2; p=0.001), indicating that service accessibility is a factor closely associated with the health status of DM patients with TB risk. These access barriers likely contribute to delayed diagnosis and suboptimal DM management. This aligns with a systematic review by Banilai & Sakundarno (2023), which concluded that healthcare-related determinants—physical, financial, and organizational—are the main barriers to TB prevention in DM patients. This finding is supported by a cohort study showing that DM patients who reported financial difficulties in accessing services had a 2.4 times greater risk (OR=2.4; 95% Cl: 1.8-3.1) of having HbA1c levels above 9.0% (severe hyperglycemia) compared to patients with Easy access. This chronic hyperglycemic condition has been clinically proven to weaken cellular immunity, thereby increasing the vulnerability of DM patients to reactivation of latent TB infection into active TB (Goshrani et al., 2025).

A study in Pakistan found that TB-DM patients experienced an average delay in diagnosis of 8-10 weeks after the onset of first symptoms, compared to 4-5 weeks in non-DM TB patients, with barriers to access to primary care being the main cause (Khanet al., 2021).

Poor access to healthcare is a strong independent predictor of pulmonary TB incidence in DM patients. Systemic interventions (expanding TB screening in DM services, integrating services, strengthening diagnostic capacity, reducing financial and transportation barriers) are highly recommended to reduce the burden of TB in the DM population.

CONCLUSION

Based on the results of research and discussion regarding the factors that cause Pulmonary Tuberculosis in Diabetes Mellitus patients at Tgk Chik Ditiro Sigli Regional Hospital, it can be concluded that there are several independent risk factors that play a role in increasing the incidence of Pulmonary TB. The most dominant factor is poor glycemic control, where patients with uncontrolled blood sugar levels have a higher risk of developing Pulmonary TB than patients with controlled glycemic levels. In addition, limited access to health services also increases the likelihood of Pulmonary TB in diabetes patients. Poor nutritional status, especially malnutrition, also contributes to the increased susceptibility of patients to Pulmonary TB infection. In addition, socioeconomic conditions indicated by low income levels are also a factor that influences the incidence of Pulmonary TB in diabetes mellitus patients. Overall, the combination of clinical factors, access to health services, nutritional status, and socioeconomic conditions are important factors that influence the risk of Pulmonary TB in DM patients.

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