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Tuberculosis Screening Using Multi-Objective Gradient Evolution-Based Support Vector Machine and C5.0 Decision Tree Method

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ABSTRACT

Tuberculosis (TB) is an infectious disease cause by *Mycobacterium tuberculosis* that typically affects the lungs, but also can affect any organ in the body. This study aims to obtain a screening model for early detection of tuberculosis using the multi-objective gradient evolution-based support vector machine and c5.0 decision tree method based on tuberculosis risk factors on Palembang City. This was a case-control study with an analytic observational design. Data were collected by interview and physical examination on 240 respondents for each case and control group. Analysis for the risk factors of tuberculosis in this study used binary logistic regression analysis. Establishment of TB early detection model using gradient evolution algorithm. In this study, the majority of respondents with TB were male (60%), 35 - 39 years old (70%), had elementary school education (60%), were underweight (78.6%), had sufficient income (54,7%), were active smokers (68.6%), lived in the same house as TB patients (94.9%), lived in a densely populated house (54.6%), and did not have BCG immunization (59.5%). Risk factors for TB incidence in Palembang City were statistically significant for gender, education, nutritional status, smoking habits, household contact, family size, and BCG immunization while age were not risk factors for TB in Palembang City. Based on the TB screening model using the GE-SVM algorithm, the accuracy rate for training data is 80.83%, while it is 74.61% for testing data. The simulation results show that the model produced in this study can help medical personnel in conducting initial screening of TB risk to a person.

Keywords: tuberculosis, risk factor, gradient evolution, support vector machine, decision tree.

1. INTRODUCTION

Tuberculosis (TB) is one of the world's top ten infectious disease-related deaths.[1] TB is caused by *Mycobacterium tuberculosis* infection, which spreads when a person with TB coughs and expel the bacteria into the air.[1] The bacteria commonly infiltrate the lungs (causing pulmonary TB), but they can also affect other organs (extrapulmonary TB). Approximately one-quarter of the global population is infected with *M. tuberculosis* and thus at risk of developing TB disease. According to the most recent World Health Organization (WHO) estimates, 10.4 million people were infected with tuberculosis in 2016, with another 1.6 million dying from the disease.[1,2] Nevertheless, most people with tuberculosis can be cured with timely diagnosis and treatment with first-line antibiotics for six months, and subsequent transmission of infection can be limited.

Because the incidence of TB varies from country to country, the disease burden also varies greatly between countries. It is currently estimated that 130 new cases of tuberculosis are diagnosed per 100,000 people each year.[3] TB disease affects both men and women of all ages, but the burden is greatest among men aged 15 and older, who accounted for 57% of all TB cases in 2018.[3]

Despite the fact that TB incidence rates have remained relatively stable in recent years, the number of new TB cases is increasing in most countries. However, the actual number of TB cases and deaths each year can be reduced by lowering the prevalence of health-related risk factors for TB. Smoking, diabetes, and HIV infection are all thought to be risk factors for tuberculosis. Some of the measures that can help reduce the incidence of TB are preventive treatment of TB infection, multisectoral policy measures, and control of the determinants of TB infection (e.g., poverty, housing quality, and malnutrition).[1,3]

Due to the slow decrease in TB incidence, efforts to find new TB control strategies are needed. Some of the current areas of focus are strategies to increase TB drugs, develop a TB vaccine, and design shorter TB regimens. However, knowledge of TB risk factors is believed to be potentially more effective for controlling TB in the community. HIV infection, male, comorbidities such as diabetes, family history of TB, lack of BCG immunization, smoking, alcohol use, single marital status, overcrowding, and poor socioeconomic status, particularly in developing countries, are all thought to be risk factors for tuberculosis.

Support vector machine (SVM) is one of the algorithms that can be used to solve data regression and classification problems. This method has been widely used in medical applications and has produced positive results. Non-linear SVM has two parameters: the SVM weight parameter and the Gaussian kernel parameter. Because these two parameters have a significant impact on SVM performance, the Gradient Evolution Base algorithm is used in this study to determine the best parameters. The Gradient Evolution Base (GE) algorithm is a metaheuristic algorithm based on an optimal value search method known as the Newton-Raphson method. The GE algorithm converts all possible solutions to the problem into a vector.

Therefore, screening examinations are required to identify early the risk variables that mostly impact the incidence of tuberculosis. Knowing the risk factors for tuberculosis allows for the development of TB control policies, such as building a promotional and preventive effort. The purpose of this study is to identify and assess risk factors thought to contribute to the spread and development of tuberculosis incidence in Palembang City and obtain a TB early detection screening model using the Multi-Objective Gradient Evolution-Based Support Vector Machine and C5.0 Decision Tree methods based on TB risk factors.

2. METHOD

This is a case-control research study with an analytic observational design. The case population was TB patients who received treatment at health centers in Palembang City, and the control population was people who did not suffer from TB (Non-TB) in the study area. The research location was health centers in Palembang city, including health centers and hospitals in Palembang city. The sampling method used in each group was incidental purposive and 240 samples were obtained in each group. The inclusion criteria of this study were 15 years old and willing to become respondents. The exclusion criteria for this study were suffering from other chronic diseases and TB patients who had recovered.

Variables taken from this study consisted of sex, age, education, nutritional status, economic status, smoking habits, household contact, family size, and BCG immunization. Furthermore, the variables was made into categorical data with the following categories: pulmonary TB incidence (TB positive and TB negative), sex (male and female), age (grouped every 5 years increments with the youngest group being the <20 years age group), education (elementary, middle high, high school, and high education), nutritional status (poor/thin nutrition if BMI <18.49; good/healthy nutrition if BMI 18.50 - 22.99; overnutrition/fat if BMI ≥23.00), economic status (insufficient if average income ≤ Rp2. 500,000 and sufficient if the mean income was >Rp2,500,000), smoking habit (yes and no), household contact (yes and no), family size (small family is defined as if the number of family members living in the same house was ≤4 people whereas a large family is defined as if the number of family members living in the same house was >4 people), BCG immunization (yes and no).

Data in the study were taken by interview using an interview guide (list of questions) and physical examination to determine the presence or absence of BCG immunization scars on the upper arm. The SPSS 24.0 program was used to process the data in this study. The descriptive analysis was used in this study to identify the description of the research subjects, both univariate and bivariate. Analysis of risk factors for pulmonary TB both partially and simultaneously was carried out using binary logistic regression analysis. Then the formation of the TB early detection model using the GE-SVM algorithm with several stages and then using the C5.0 decision tree.

3. RESULT

In this study, there were 480 respondents consisting of 240 people with tuberculosis and 240 people without tuberculosis. Of the 480 respondents, there were 260 males (54.2%) with 156 TB patients (60%) and 220 females (45.8%) with 84 TB patients (38.2%). Sex is a risk factor for the occurrence of tuberculosis in Palembang City. Males are more likely than women to suffer tuberculosis. (p-value 0.000; OR 2.429; 95% CI 1.681-3.509).

The average age of responders was 43.33 years, with the youngest being 16 years old and the oldest being 79 years old. TB was most prevalent among respondents aged 35 - 39 years (70.0%). Furthermore, TB patients in the age group of 30 - 34 years amounted to 61.5%, the age group of 45 - 49 years amounted to 61.2%, the age groups of 60 - 64 and 70 - 74 years each amounted to 57.1%, and the age group of 65 - 69 amounted to 55.0%. This data shows that TB patients in Palembang city are proportionally distributed in each age group. Age was not a risk factor for TB incidence in Palembang City. The risk of respondents aged >30 years of age suffering from TB was greater when compared to respondents aged ≤30, but statistically insignificant (p-value: 0.214; OR 1.295; 95%CI 0.861-1.948).

Respondents who graduated from elementary school amounted to 90 people (18.8%) with 54 people with TB (60.0%). Respondents who graduated from middle school were 103 people (21.5%) with 41 people with TB (39.8%). Respondents who graduated from high school were 178 people (37.1%) with 97 people with TB (54.5%). Respondents with high education (D3, S1, and S2) totaled 109 people (22.7%) with 48 people with TB (44.0%).

Education is a risk factor for TB incidence in Palembang city. The risk of respondents with primary school education suffering from TB was greater than those with junior high school, high school, and university education, and was statistically significant (p-value: 0.036; OR 1.645; 95% CI 1.032-2.622).

Nutritional status is a risk factor for the occurrence of tuberculosis in Palembang city. TB patients with poor nutritional status amounted to 78.6% while those with healthy nutritional status amounted to 42.7%. The risk of respondents with poor nutritional status suffering from TB is greater when compared to respondents with healthy nutritional status, and statistically significant (p-value: 0.000; OR 4.926; 95% CI 2.919 - 8.314).

Economic status is not a risk factor for the occurrence of tuberculosis in Palembang city. Respondents with insufficient income amounted to 266 people (55.4%) with 123 TB patients (46.2%) and respondents with sufficient income amounted to 214 people (44.6%) with 117 TB patients (54.7%). The risk of respondents with insufficient economic status suffering from TB is lower when compared to respondents with sufficient economic status. The risk of respondents with insufficient economic status suffering from TB was OR = 0.713 times when compared to respondents with sufficient economic status, but was not statistically significant (p-value: 0.067; 95%CI 0.497-1.023).

Smoking habit is a risk factor for TB in Palembang city. Respondents who had a smoking habit totaled 159 people and all of them were male. There were no female respondents who were active smokers. Of the 159 male active smokers, 109 people (68.6%) had TB. Male smokers were at a higher risk of tuberculosis than male nonsmokers, and was statistically significant (p-value: 0.000; OR 3.162; 95% CI 2.115 - 4.726).

Household contact is a risk factor for the occurence of tuberculosis in Palembang city. Respondents who lived in the same house with TB patients totaled 59 people (12.3%) with 56 TB patients (94.9%) and respondents who did not live with TB patients totaled 421 people (87.7%) with 184 TB patients (43.7%). Those who shared a home with TB patients had a higher risk of becoming infected than those who did not share a home with TB patients (p-value: 0.000; OR 24.043; 95% CI 7.407-78.040).

Family size is a risk factor for the occurrence of tuberculosis in Palembang city. Respondents living in small families totaled 196 people (40.8%) with 85 people (43.4%) suffering from TB. Respondents living in large families totaled 284 people (59.2%) with 155 people (54.6) suffering from TB. Respondents who lived in a densely populated house (>4 occupants) had a higher chance of having TB (54.6%) when compared to respondents who lived in a sparsely populated house (≤4 occupants) (p-value: 0.016; OR 1.569; 95% CI 1.088-2.264).

There were 280 respondents who received BCG vaccine immunization (58.3%) with 212 TB patients (43.25). Respondents who did not immunize with the BCG vaccine were 200 people (41.7%) with 119 people with TB (59.5%). Those who did not obtain appropriate BCG immunization had a higher risk of developing tuberculosis than those who did receive adequate BCG immunization (p-value: 0.000; OR 1.931; 95% CI 1.336-2.790). Therefore, BCG vaccine immunization is a risk factor for TB incidence in Palembang city.

Simultaneous analysis of TB risk factors was conducted to obtain variables that were dominant risk factors for TB in Palembang City using binary logistic regression analysis with the Backward LR method. According to the findings of the analysis, only four of the nine risk factor variables are prominent in the risk of tuberculosis incidence in Palembang City, namely household contact, nutritional status, smoking habits, and BCG immunization.

Table 1. Dominan Risk factors for TB Incidence

Variables	**TB Incidence**			
	Beta	*p-value*	OR	95% CI OR
Constant	-1,398			
House contact (Yes)	3,370	0,000	29,069	(8,755 ; 96,521)
Nutritional Status (Poor)	1,684	0,000	5,388	(3,078 ; 9,431)
Smoking habit (Yes)	1,037	0,000	2,821	(1,796 ; 4,433)
BCG Immunization (No)	0,541	0,013	1,718	(1,120 ; 2,637)

The result of the GE-SVM algorithm is a model that can classify a person at high or low risk of TB based on the nine risk factors above. In general, the level of accuracy produced by the GE-SVM classification model has an accuracy rate for training data of 80.83% and testing data accuracy of 74.61%. From these results, it is expected that the prediction of new data has an accuracy rate of around 74.61%. The simulation results show that the model produced in this study can help medical personnel in conducting initial screening of TB risk to a person.

Table 2. Simulation Results of GE-SVM Model for TB/Non TB Classification

Replication	**Training Accuracy**	**Testing Accuracy**	**Spreading Distance**
1	80,83%	74,41%	0,964
2	80,81%	72,20%	0,910
3	80,86%	73,22%	0,945
4	80,81%	72,70%	0,937
5	80,86%	72,09%	0,966
6	80,83%	73,04%	0,963
7	80,79%	74,00%	0,971
8	80,79%	74,61%	0,976
9	80,86%	73,43%	0,958
10	80,86%	73,43%	0,958
Mean	**80,83%**	**73,31%**	**0,955**
Minimum	**80,79%**	**72,09%**	**0,910**

Maximum	**80,86%**	**74,61%**	**0,976**

To enrich the analysis of the influence of independent variables on TB risk prediction, this study applied another classification method, namely the decision tree (DT) analysis. Basically, this method builds a decision model from the data we already have. From the processing results, the following decision tree model is generated from the data in this study.

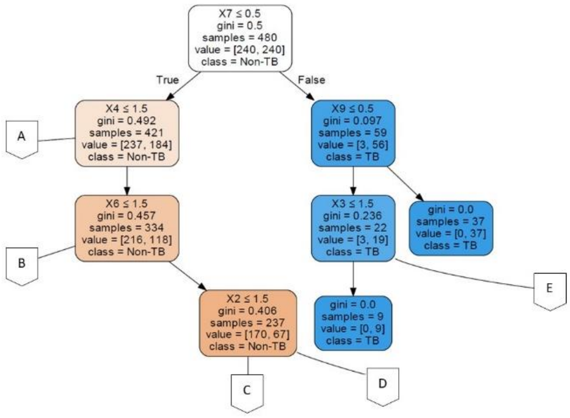

Figure 1. Decision Tree Part 1

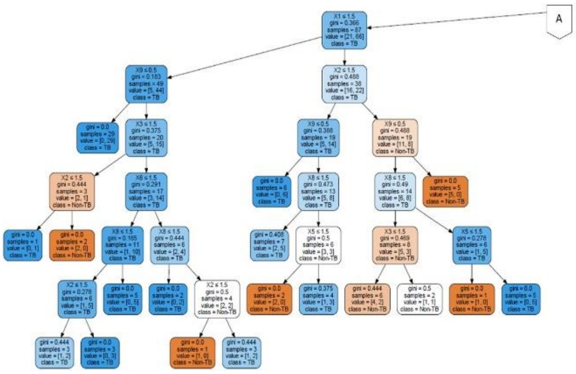

Figure 2. Decision Tree Part 2

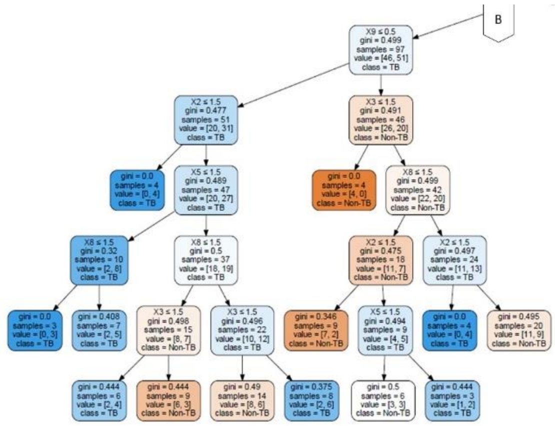

Figure 3. Decision Tree Part 3

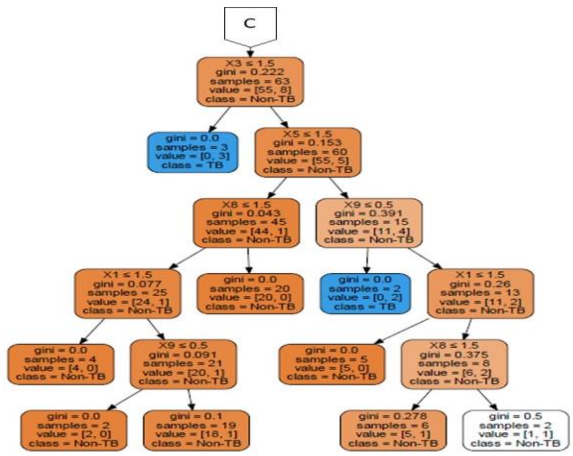

Figure 4. Decision Tree Part 4

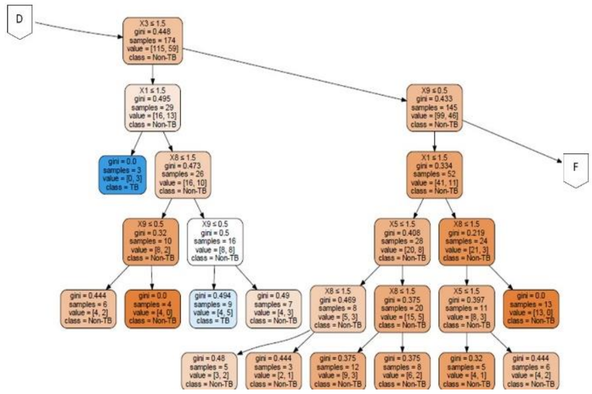

Figure 5. Decision Tree Part 5

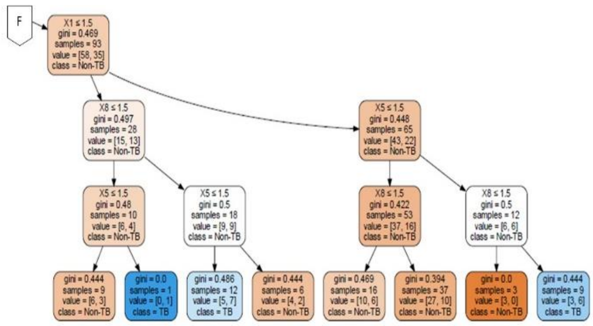

Figure 6. Decision Tree Part 6

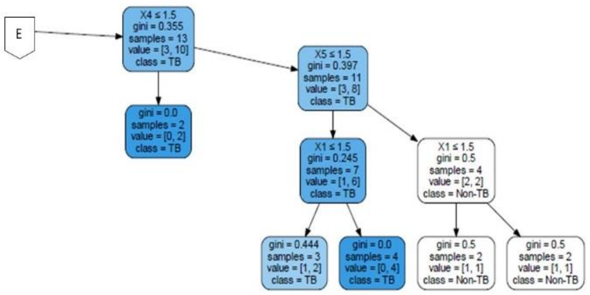

Figure 7. Decision Tree Part 7

The decision tree above forms a relationship between variables that can predict whether a person is at high or low risk of TB infection. Examples of rules formed from the decision tree above are as follows.

Rule 1

$\{X7 = 0, X4 = 1, X1 = 1, X9 = 0\} \Rightarrow$ TB.

This means that if a person has no household contact with other TB patients, is malnourished, male, and not immunized against BCG then he will be at high risk of TB infection.

Rule 2

$\{X7 = 0, X4 = 1, X1 = 1, X9 = 1, X3 = 1, X2 = 1\} \Rightarrow$ TB.

That is, if a person has no household contact with other TB patients, is nutritionally deficient, is male, has BCG immunization, has primary education, and is less than 30 years old, he or she will be at high risk of TB infection.

Rule 3

$\{X7 = 1, X9 = 0, X3 = 1\} \Rightarrow$ TB.

This means that if a person is in close contact with other TB patients, does not have BCG immunization, and has a primary education, he or she will be at high risk of TB infection.

Rule 4

$\{X7 = 1, X9 = 0, X3 = 1\} \Rightarrow$ TB.

This means that if a person is in close contact with other TB patients, does not have BCG immunization, and has a primary education, then he or she will be at high risk of TB infection. There were 9 cases of people with TB.

Rule 5

$(X7=0, X4=1, X1=0, X2=1, X9=0) \Rightarrow TB.$

This means that if a person has no household contact with TB patients, is malnourished, female, less than 30 years old, and not immunized against BCG, then they will be at high risk of TB infection. There were 6 cases of TB patients.

Rule 6

$(X7=0, X4=0, X6=1, X9=0, X2=1) \Rightarrow TB.$

This means that if a person has no household contact with TB patients, is well-nourished, a smoker, not immunized against BCG, and is less than 30 years old, then he or she will be at high risk of TB infection. There are 4 cases of TB patients.

Rule 7

$(X7=0, X4=0, X6=1, X9=1, X3=0, X8=0, X2=1) \Rightarrow TB.$

This means that if a person has no household contact with TB patients, is well-nourished, a smoker, has had BCG immunization, has an upper secondary education, sufficient family size, and is less than 30 years old, then he or she will be at high risk of TB infection. There were 4 cases of TB patients.

Rule 8

$(X7=0, X4=0, X6=1, X9=0, X2=0, X5=1, X8=1, x3=1) \Rightarrow TB.$

This means that if a person has no household contact with TB patients, is well-nourished, a smoker, is not immunized against BCG, is over 30 years old, has poor economic status, has a dense family size, and has a primary education, he or she will be at high risk of TB infection. There are 3 cases of TB patients.

Rule 9

(X7=0, X4=0, X6=1, X9=0, X2=0, X5=1, X8=0, X3=0) $\Longrightarrow TB$.

This means that if a person has no household contact with TB patients, is well-nourished, a smoker, is not immunized against BCG, is over 30 years old, has a low economic status, has an adequate family size, and has a middle to upper class education, he or she will be at high risk of TB infection. There were 7 cases of TB patients.

Rule 10

(X7=0, X4=1, X1=0, X2=1, X9=0) $\Longrightarrow TB$.

This means that if a person has no household contact with TB patients, is malnourished, female, less than 30 years old, and not immunized against BCG, then he or she will be at high risk of TB infection. There were 6 cases of TB patients.

Rule 11

(X7=0, X4=1, X1=0, X2=1, X9=1, X8=0, X5=0) $\Longrightarrow TB$.

This means that if a person has no household contact with TB patients, is undernourished, female, less than 30 years old, immunized against BCG, has sufficient family size, and has sufficient economic status, he or she will be at high risk of TB infection. There were 2 cases of TB patients.

Rule 12

(X7=0, X4=1, X1=1, X9=1, X3=1, X2=1) $\Longrightarrow TB$.

This means that if a person has no household contact with TB patients, is malnourished, male, BCG immunized, has primary education, and is over 30 years old, then he or she will be at high risk of TB infection. There was 1 case of TB patient.

4. DISCUSSION

This study discovered that male TB patients outnumbered female TB patients. Based on the most recent data from the Global Tuberculosis Report 2019, the findings of this study are compatible with the demographic distribution of TB patients. The 2019 Global Tuberculosis Report reported that most TB patients were male (5.7 million patients), while the rest were female (3.2 million patients).[4] These findings are also consistent with the rest of TB epidemiologic research, which show that the majority of TB patients are male, with percentages ranging from 55-71%.[8,12,13,14,15]

The discrepancy between male and female incidence rates is assumed to be linked to biological differences, which alter illness susceptibility. Another possible reason for the difference in TB occurence between male and female is the different ability to access health services between the two sexes in some developing countries due to cultural differences.[16] In general, males are thought to be more at risk of TB because the male population has more opportunities to come into contact with TB patients and become infected due to different social roles in the community and high levels of social activity.[2]

In this study, TB patients were more common among responders aged 35 to 39 years. This is consistent with prior research, which found that many TB patients are young adult between the ages of 15 and 44.[4,8,9,10.] According to the findings, age was not a risk factor for tuberculosis incidence in Palembang City. Nonetheless, it was discovered that respondents aged >30 years had a higher risk of tuberculosis than those aged ≤30 years, however this was not statistically significant. This age group has an increased risk of tuberculosis infection, possibly because it is of productive age. The greater risk of TB in this age group is thought to be related to more frequent social contact in the community.[11]

Education is part of an individual's sociodemographic status. For a long time, the incidence of TB has been known to have problems rooted in social and economic aspects.[20] Based on the literature, people living in socioeconomic deprivation are known to be vulnerable to TB infection. This susceptibility is thought to be highly tied to individuals' and communities' degree of knowledge and understanding, which will affect their access to health services.[21] This study's findings are also consistent with earlier research demonstrating that TB patients with low education levels are twice as likely as those with a strong education to contract the disease.[17,18,19]

Most TB patients in this study had poor nutritional status, while the rest had healthy and overweight status. Many previous studies have shown that poor nutritional status or malnutrition, both micronutrient and macronutrient deficiencies, can increase the risk of TB.[22] Pathophysiologically, a person with nutritional disorders is known to have an impaired immune system, in the form of a decreased immune response.[22,23] This decreased immune response then facilitates *M.tuberculosis* infection into a person's body and eventually suffer from TB.

In theory and in previous studies, undernutrition and TB can influence each other. Malnutrition is known to increase a person's risk of TB infection, while TB can also lead to undernutrition. Reduced appetite, as one of the clinical signs of tuberculosis, and metabolic alterations in TB patients can lead to changes in nutritional status from good to poor or malnutrition.[24] Therefore, the incidence of malnutrition or poor nutritional status is often very common among TB patients. However, with proper TB treatment, it is expected that the nutritional status of patients can gradually improve.

In this study, it was found that the risk of respondents with insufficient economic status suffering from TB was lower when compared to respondents with sufficient economic status. In various studies, TB is recognized as a disease that is often associated with low or insufficient economic status. Many studies have found that an increased incidence of tuberculosis infection is linked to unemployment, a lack of education, and migration, all of which are caused by poverty, a socioeconomic status indicator. Unfortunately, there is currently inadequate data on the relationship between socioeconomic position and tuberculosis in poor nations.[25]

This study discovered that smoking is a risk factor for the occurrence of tuberculosis. This is consistent with prior research indicating that smoking increases the incidence of clinical TB and is the cause of half of all male TB deaths and a quarter of all male deaths in middle age, with the risk of developing pulmonary TB increasing with the dose and duration of smoking.[1,31]

House contact is contact with people with TB who live in the same house as the respondent. In this study, it was discovered that household contact was a risk factor for tuberculosis. The findings of this study support multiple earlier studies' findings that increasing the number of persons in the home, particularly adults, can double the risk of tuberculosis, which has been validated by numerous investigations.[30] This is mostly due to poorly maintained house conditions such as closed home types, a lack of rooms, windows, and poor construction materials, which results in overcrowding and poor ventilation, increasing the risk of pulmonary TB transmission.[25]

This study discovered that family size is a risk factor for tuberculosis. Those who live in densely populated areas have a higher risk of contracting tuberculosis than those who reside in sparsely inhabited areas.[26] Previous research has indicated that children from densely packed households are substantially more likely to contract tuberculosis. The pathophysiology of successful transmission of these bacteria in families via minute droplets is often linked to the fact that TB rates are associated with crowded households.[26,27]

BCG immunization is known by conducting a physical examination to determine the presence or absence of BCG immunization scar on the upper arm of the respondent. It was discovered that BCG immunization is a risk factor for the occurrence of tuberculosis. Those who had insufficient BCG immunization had a higher risk of contracting TB than those who had adequate BCG immunization. This is in accordance with several previous studies where BCG vaccine was experimentally administered to animals and then the relationship was observed when exposed to TB bacteria. Meanwhile, experimental studies in humans are still in the process of further research to determine the specific relationship.[28,29]

5. CONCLUSION

Based on the analysis, gender, education, nutritional status, smoking habit, household contact, family size, and BCG immunization are risk factors for TB in Palembang city, while age and economic status are not risk factors for TB in Palembang city. And then, the GE-SVM algorithm and C5.0 decision tree model study may be used by medical personnel in conducting initial screening of TB risk to a person.

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