JKKI: Jurnal Kedokteran dan Kesehatan Indonesia
Indonesian Journal of Medicine and Health
Journal homepage: https://journal.uii.ac.id/JKKI
P-ISSN 2085-4145 | E-ISSN 2527-2950

Spatial analysis of tuberculosis cases among stunted toddlers in Rambipuji District, Jember Regency

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Original Article

ARTICLE INFO
Keywords:
childhood tuberculosis,
Moran's Index,
Nearest Neighbor Index,
spatial analysis,
stunted toddler
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DOI: 10.20885/JKKI.Vol15.Iss2.art8
History:
Received: February 5, 2024
Accepted: August 23, 2024
Online: August 27, 2024

ABSTRACT

Background: The ongoing prevalence of tuberculosis (TB) and stunting presents significant health challenges, frequently localized within specific regions of Indonesia. Spatial analysis is essential in controlling infectious diseases like TB, as it identifies disease clusters and patterns of local TB spread within an area.
Objective: This study aimed to analyze the distribution of TB cases among stunted children through spatial analysis.
Methods: We used a cross-sectional analytical descriptive study. We interviewed parents of stunted children using a questionnaire. The diagnosis of TB was made based on the pediatric TB scoring table. Coordinate data of sample sites were obtained using a Geographic Information System (GIS), supported by risk factor analysis of TB. We then created a disease distribution map using the spatial analysis by Moran's Index and Nearest Neighbor Index (NNI) methods.
Results: There were 15 childhood TB cases (8.2%) among stunted children in Rambipuji District. The spatial autocorrelation test using Moran's index showed that TB cases were clustered in Rambigundam village (Moran's index 0.2364, p-value <0.05 and Z-score >1.96). The results of the NNI analysis showed dispersed results (p-value=0.000) in all villages.
Conclusion: The distribution of childhood TB cases among stunted children in Rambipuji District is primarily random, except for Rambigundam Village, which shows a clustering of cases. According to the NNI methods, childhood TB cases among stunted children are spreading throughout all villages. These results underscore the need for initiatives to curb TB transmission, especially among stunted children, which should be targeted at all villages.

INTRODUCTION

Tuberculosis stands among the decadal causes of mortality on a global scale, and Indonesia is the third most afflicted nation by TB worldwide, trailing only India and China.[1] As per the Global TB Report 2021, Indonesia faces around 824,000 TB cases, but only 393,323 cases (48%) have been detected, treated, and officially recorded in the national database.[1] Within East Java Province, Indonesia, Jember occupies the second position in the prevalence of TB cases, encompassing 4,497 conventional cases, 193 instances of drug-resistant TB, and 457 cases of childhood TB.[2]

Rambipuji District in Jember reported a TB prevalence rate of 348 cases per 100,000 people in 2022 (16.3% of the population). By 2023, according to the Jember Health Office, there was a significant decrease in the total number of TB cases in the district, with only 99 cases recorded, including 20 cases of childhood TB.[2] Further data from the Jember Health Office in 2023 showed a marked alteration in the tuberculosis incidence within the Rambipuji District, which displayed the continual efforts to mitigate and regulate this public health issue.

Stunting in toddlers is marked by insufficient consumption of carbohydrates, proteins, and essential macronutrients to produce antibodies and lymphocytes for immunity. This insufficiency leads to compromised immunity, making stunted toddlers more prone to infections. The repercussions of stunting extend to the child's capacity to resist various infections, such as TB. Stunted toddlers are more susceptible to TB compared to their non-stunted peers. These conditions underscore the complex correlation between nutritional status and susceptibility to infectious diseases, highlighting the importance of sufficient nutrition in bolstering a child's overall health and immune response.[3] According to the Rambipuji Public Health Center, in August 2023, there was an increased prevalence of stunted children under five in the Rambipuji district of Jember, totaling 649 children (19.12%).[4] Those data exceed the national goal of 14%, signaling a critical issue regarding child health and nutrition in the area. It emphasizes the necessity for increased alertness in the Rambipuji district since children are vulnerable to infections due to their developing immune systems. The presence of TB patients in the region heightens the potential risk of TB transmission to this vulnerable group.

Tuberculosis is a disease that tends to cluster. Clustering, in the context of disease spread, refers to the spatial grouping or space-time pattern of cases, which is significant in their characteristics.[5] This means that TB patients, who often have low social determinants of health, tend to live near each other or in groups with other individuals who also have low social determinants of health. This clustering increases their risk of contracting TB, as the disease can spread more easily within these groups.

In epidemiology, spatial analysis is instrumental, especially for assessing the occurrence of differences in incidence according to geographical areas and identifying disease clustering.[5] Spatial analysis of TB cases can identify disease clusters and patterns in the local spread of TB. Identifying these clusters helps stakeholders plan and focus control efforts on areas of higher risk and helps identify environmental risk factors associated with the spread of TB. By combining TB data with environmental data, such as population density, access to health services, and the physical condition of housing, spatial analysis can help identify patterns of association between environmental risk factors and TB incidence.[6] This information can be used to design interventions to reduce risk factors for TB transmission, monitor the spread of TB over time, and evaluate the effectiveness of interventions. By comparing spatial data before and after an intervention, spatial analysis can help measure the impact of the intervention on TB spread and identify areas that need additional attention. This analysis allows for more effective and targeted monitoring of TB control strategies.[7] In this study, we aimed to analyze the distribution of tuberculosis cases in stunted children in Jember based on spatial analysis. Our results will provide additional material for epidemiological studies on area-based disease control, especially TB.

METHOD

Study design

We used an analytical descriptive approach utilizing a cross-sectional design. Data were gathered from a sample through interviews, direct observation, and examinations for childhood TB in Rambipuji District, Jember Regency, from August to September 2023. This study focused on the population of under-five stunted children in Rambipuji District, totaling 649 children. The sampling method employed was proportional random sampling, resulting in a sample size of 183 children. We selected samples from eight villages (Pecoro, Rambipuji, Rambigundam, Gugut, Kaliwining, Nogosari, Rowotamtu, and Curahmalang) in Rambipuji District, proportionate to the percentage of stunted children in each village.

Inclusion criteria

We included children under the age of five at the time of data collection who met the stunting criteria according to the World Health Organization (WHO) Z-score curve, where a child's height-for-age Z-score fell below minus two standard deviations (-2 SD). Additionally, participation required the willingness of parents or guardians of the child respondents, demonstrated through signed informed consent. Children with congenital disabilities and severe illnesses during data collection were excluded from the study.

Data collection

Data were collected by interviews, direct observations, examinations for childhood TB, and spatial data collection. Interviews were conducted with parents or guardians of child respondents using a questionnaire. Furthermore, direct observations and measurements were performed to assess the physical attributes of the respondents' residences, including household occupancy, ventilation space, household lighting, room temperature, and humidity. Measurements were taken using a rolling meter, lux meter, and thermohygrometer.

The diagnosis of tuberculosis in children was determined using the pediatric TB scoring system, as detailed in Table 1. After the doctor or trained nurse conducted anamnesis, physical examination, and supporting examinations, the weighting was then performed using a pediatric TB scoring system for the following eight parameters: close contact of TB patient; tuberculin skin test or Mantoux test; body weight/ nutritional status; unexplained fever; cough; enlargement of lymph nodes in the neck, armpits, groin; swelling of bones/joints in the pelvis, knees, phalanges; and chest X-ray. The score range given for each parameter was 0-3. Patients with a total score ≥ 6 should be managed as TB patients and receive anti-tuberculosis drugs. If the score was less than six but clinically the suspicion of TB was strong, further diagnostic examinations were conducted, such as chest X-ray and tuberculin skin test (TST).[8] The tuberculin skin test involved administering 0.1 ml of PPD (Purified Protein Derivative) reagent intracutaneously on the inner surface of the child's forearm at an angle of 5-15 degrees. Readings were taken 48-72 hours following the injection.[8]

Spatial analysis was used to describe all variables. The first step was to make a basic map of the Rambipuji District, Jember, using the Indonesian land map (Rupa Bumi Indonesia map). The process of determining the distribution of TB infection and stunted children was carried out by visiting the sample houses. The coordinates of each house visited were recorded using GPS (Global Positioning System) and plotted on the map.

Ethics

The research protocol has received approval from the Faculty of Medicine Ethics Committee, Jember University, Number: 1.773/H25.1.11/KE/2023.

Table 1. Pediatric tuberculosis scoring table[8]

Parameters	Score 0	Score 1	Score 2	Score 3	Total
Close contact of TB patient	No/ unknown		Family report; ARB-negative or unknown	ARB-positive	
Tuberculin skin test or Mantoux test	Negative			Positive	
Body weight/ nutritional status		Below the red-line (weight/age <80%)	Clinical malnutrition (weight/age <60%)		
Unexplained fever		≥2 weeks			
Cough		≥3 weeks			
Enlargement of lymph nodes in the neck, armpits, or groin		≥1 cm, total >1, not painful			
Swelling of bones or joints in the pelvis, knees, or phalanges		Swelling			
Chest X-ray	Normal/ unknown		Suggestive for TB		
Total					

ARB: Acid-Resistant Bacteria; TB: tuberculosis

Data analysis

Information regarding childhood TB risk factors underwent multivariate logistic regression analysis, maintaining a confidence level of 0.05 and a 95% confidence interval (CI or α=0.05). Data analysis encompassed various risk factors, including anthropometric status, history of close TB contact, Bacillus Calmette-Guerin (BCG) vaccination history, parental smoking habits, parental income, household occupancy, ventilation space, household lighting, room temperature, and humidity. Data for spatial analysis in the form of coordinate points of research sample locations with positive childhood TB cases and their risk factors will be processed using spatial autocorrelation (Moran's Index) and NNI analysis with ArcGIS 10.6 software.

RESULT

We investigated 183 stunted children from Rambipuji District, Jember, who underwent testing for TB. From 183 samples, 15 children were tested positive for TB (8.2%). Those TB cases were spread across seven of the eight villages where the research was conducted (Figure 1). Pecoro Village has the highest incidence of childhood TB cases, with 4 cases (2.2%), whereas Curahmalang Village has no reported cases. Researchers found three childhood TB cases in Gugut Village; 2 cases in Rambipuji, Kaliwining, and Rambigundam Villages; and 1 case each in Nogosari and Rowotamtu Villages.

Figure 1 shows the occurrence of TB among stunted children within Rambipuji District, offering vital perspectives into the correlation between nutritional status and TB prevalence in this demographic. The detection of confirmed cases emerged the need for further examination and highlighted the significance of tailored interventions to tackle the health issues confronting stunted children in the area.

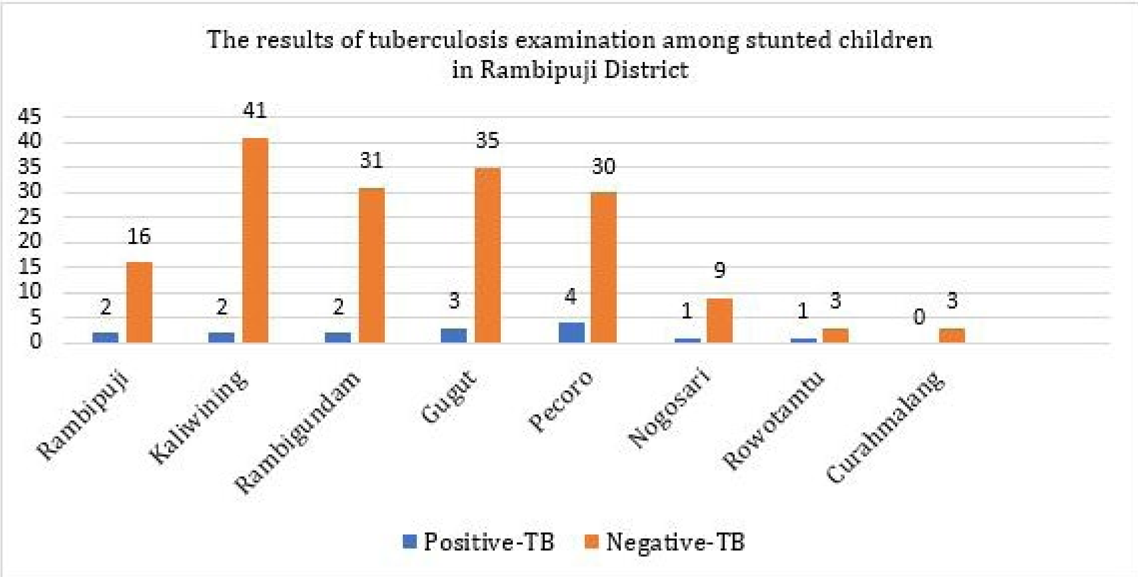

Figure 1. The results of tuberculosis (TB) examination among stunted children in Rambipuji District

Following the initial data analysis, we investigated a multivariate analysis with binary logistic regression. The multivariate analysis unveiled some specific risk factors that significantly influenced the incidence of childhood TB. Among those factors, anthropometric status emerged as an influential contributor, particularly in stunted and very stunted conditions. Furthermore, the history of close TB contact and household occupancy emerged as significant determinants, with each factor demonstrating a statistically notable correlation, with a p-value less than 0.05 (Table 2). This detailed analysis offers a more profound comprehension of the diverse array of risk factors influencing the occurrence of childhood tuberculosis within the research population. Recognizing the interplay of these variables is essential for developing targeted interventions and public health strategies aimed at mitigating the impact of these risk factors and reducing the incidence of childhood TB.

Table 2. The influence of risk factors on the incidence of childhood tuberculosis cases among stunted children in Rambipuji District

Risk factors of childhood TB	p-value	OR	95% CI for EXP(B)	
Anthropometric status	0.029*	6.718	1.220	- 36.992
History of close TB contact	0.000*	39.563	6.501	- 240.748
Household occupancy	0.015*	9.659	1.545	- 60.382

TB: tuberculosis; OR: Odd Ratio; CI for EXP(B): Confidence Interval for Exponent Beta. *p-value<0.05

Spatial analysis played a pivotal role in this study, mainly focusing on villages with reported cases of childhood TB. Intriguingly, among the examined villages, Curahmalang emerged as an anomaly, displaying no reported cases of TB in children. This absence in Curahmalang raised questions about the unique factors contributing to the absence of childhood TB in this village, warranting further investigation into potential protective factors or distinctive community practices that may be influencing the prevalence of the disease.

The application of Moran's index in the spatial autocorrelation test revealed noteworthy patterns in the distribution of childhood TB cases. Notably, Rambigundam village exhibited a distinct clustering of childhood TB infections, as evidenced by a p-value of <0.05 and a Z-score exceeding 1.96, as detailed in Table 3 and visually depicted in Figure 2. Identifying this spatial clustering is vital for understanding the localized dynamics of childhood TB transmission, paving the way for targeted interventions in areas with heightened risk. This spatial analysis identified areas of concern and provided valuable insights into the spatial patterns of childhood TB, facilitating more precise and effective public health strategies tailored to the specific needs of affected communities.

The spatial analysis focuses on the distribution pattern of TB cases among stunted children. It includes an assessment of risk factors that may contribute to spreading the disease in the Rambipuji district, as shown in Table 4.

We showed no spatial autocorrelation (random) in any of the risk factor variables examined, which was confirmed by a spatial autocorrelation analysis using Moran's index. These results suggest no significant spatial patterns or connections in the region's geographical distribution of TB risk factors.

The findings derived from the NNI analysis revealed a significant dispersion pattern within the investigated villages, with a p-value of 0.000 (Table 5 and Figure 3). This statistical measure displayed the spatial distribution of the studied phenomena, revealing a deviation from random spatial arrangement. The obtained result implied a non-random distribution of the observed attributes across the sampled villages, suggesting the presence of spatial autocorrelation or underlying spatial processes influencing the observed dispersion pattern. This analytical insight provided a basis for further exploration into the spatial dynamics and potential contributing factors that give rise to the discerned spatial heterogeneity in the studied villages.

Table 3. Spatial autocorrelation (Moran's Index) analysis of childhood tuberculosis cases among stunted children in Rambipuji District based on village area

Village	EI	Z-score	I	p-value	Autocorrelation
Gugut	-0.021	-0.733	-0.087	0.464	Random
Kaliwining	-0.009	-0.267	-0.023	0.790	Random
Pecoro	-0.029	0.150	-0.012	0.881	Random
Rambipuji	-0.034	-1.079	-0.050	0.281	Random
Rambigundam	-0.042	2.414	0.236	0.016*	Clustered
Nogosari	-0.007	-0.623	-0.008	0.533	Random
Rowotamtu	-0.024	0.583	-0.019	0.560	Random

EI: Estimated Index; I: Moran's Index. *p-value <0.05

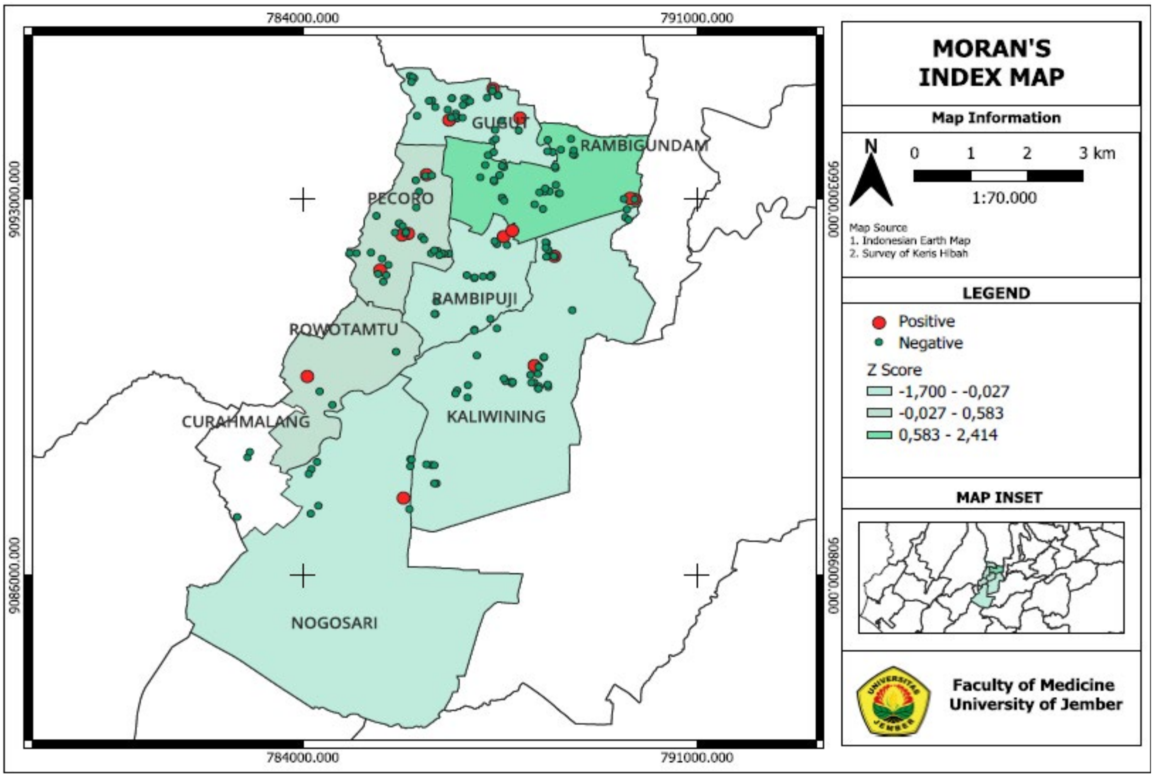

Figure 2. Moran's Index map of childhood tuberculosis cases among stunted children in Rambipuji District

Table 4. Spatial autocorrelation (Moran's Index) analysis of risk factors of childhood tuberculosis cases among stunted children in Rambipuji District

Risk Factors	EI	Z-score	I	p-value	Autocorrelation
Anthropometric status	-0.035	-1.079	-0.050	0.281	Random
History of BCG vaccination	-0.035	-1.087	-0.068	0.313	Random
Parental income	-0.002	-0.763	-0.027	0.445	Random
Parental smoking habits	-0.002	-0.655	-0.024	0.512	Random
History of close TB contact	-0.002	-0.738	-0.026	0.460	Random
Household occupancy	-0.003	0.086	0.001	0.932	Random
Ventilation space	-0.002	-0.495	-0.019	0.621	Random
Household lighting	-0.091	-0.366	-0.144	0.714	Random
Humidity	-0.002	-0.726	-0.026	0.468	Random
Room temperature	-0,002	-0.517	-0.019	0.605	Random

BCG: Bacillus Calmette-Guerin; TB: tuberculosis; EI: Estimated Index; I: Moran's Index. *p-value <0.05

Table 5. Nearest Neighbor Index analysis of childhood tuberculosis cases among stunted children in Rambipuji district

Village	Observed mean distance (m)	Expected mean distance (m)	NNI	Z-score	p-value	Result
Gugut	853.54	255.63	3.339	7.752	0.000	Dispersed
Kaliwining	2,065.09	22.72	90.889	243.189	0.000	Dispersed
Pecoro	532.36	141.85	3.753	10.504	0.000	Dispersed
Rambipuji	208.61	7.22	28.886	75.448	0.000	Dispersed
Rambigundam	71.59	4.230	16.922	43.079	0.000	Dispersed

NNI: Nearest Neighbor Index. p-value <0.05

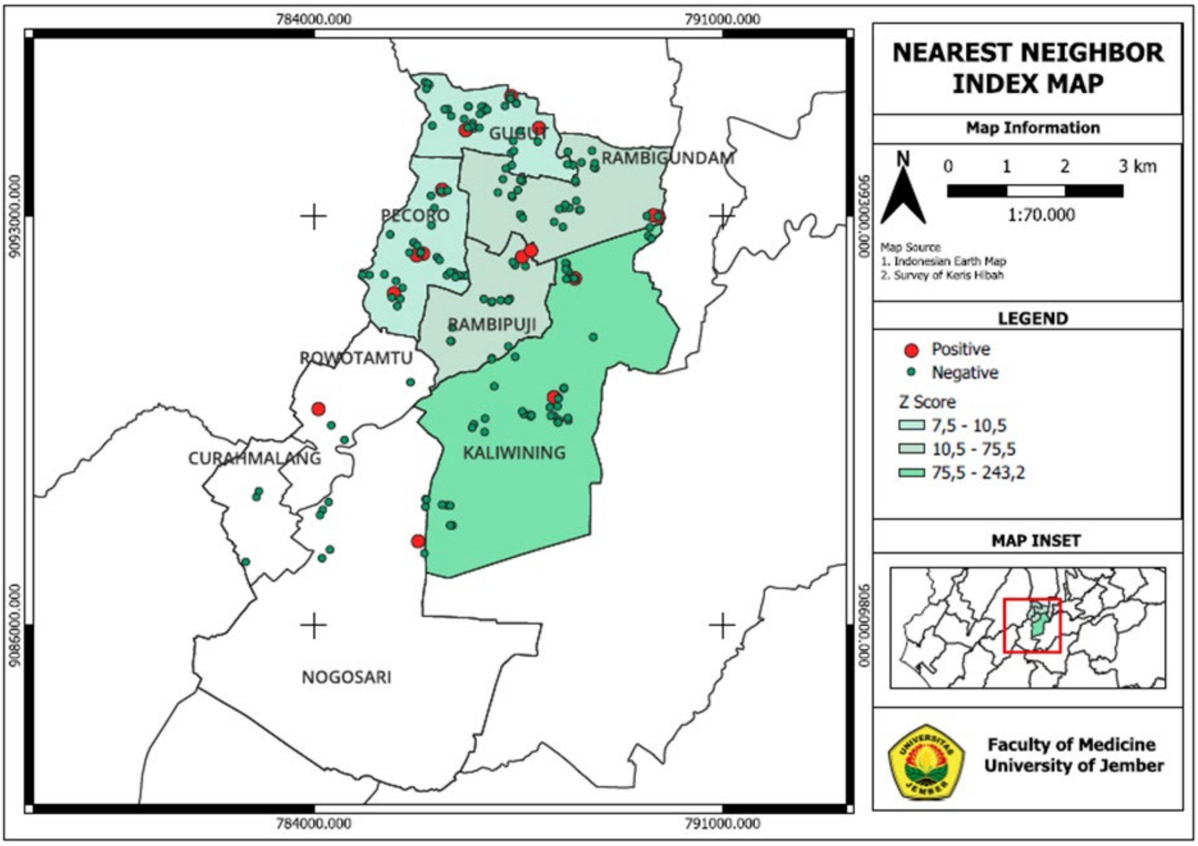

Figure 3. Nearest Neighbor Index (NNI) map of childhood tuberculosis cases among stunted children in Rambipuji District

DISCUSSION

When exploring the impact of malnutrition on TB susceptibility, it is crucial to consider the role of the thymus. This organ, which is vital in developing T lymphocytes during the perinatal and early childhood stages, holds significant importance. In stunted children, inadequate intake of essential energy and protein can decrease the thymus size and apoptosis of cortical thymocytes. This, coupled with changes in the microenvironment surrounding lymphoid and epithelial cells, alongside reduced hormone secretion and thymic cell proliferation, contributes to a weakened immune response. As a result, there is a decrease in the production of T lymphocytes occurs, significantly affecting cellular immunity in the defense against TB pathogens.[9]

By logistic regression analysis, we found a significant influence of anthropometric status on the susceptibility to childhood TB, as indicated by an Odds Ratio (OR) of 6.7 with a 95% CI ranging from 1.22 to 36.99. This statistical association underscores the substantial impact of stunted or severely stunted anthropometric status, with individuals in this category exhibiting a 6.7-fold higher likelihood of contracting TB compared to those not. This finding aligns with study by Nora et al., which reported a 5.8 times higher risk of TB incidence among children with malnutrition-related conditions, including stunting.9 Numerous studies have postulated that malnutrition, especially stunting, can exert adverse effects on gene expression and immune function, thereby serving as predisposing factors for the development of TB infection.[10]

This complex connection between malnutrition-induced changes in thymic physiology and the impact on immune function sheds light on the underlying mechanisms linking anthropometric status to TB susceptibility in children. The multifaceted nature of this relationship underscores the importance of holistic approaches to health interventions, addressing both nutritional status and immunological factors to mitigate the risk of TB in vulnerable populations.[11]

Another noteworthy factor other than anthropometric, which contributes significantly to the incidence of childhood TB, is the history of close contact with TB patients. The logistic regression analysis reveals a compelling association, with an OR of 39.6 and a 95% CI ranging from 6.50 to 240.78. This implies that individuals with a history of close contact with TB patients are strikingly 39.6 times more susceptible to developing TB compared to those without such contact. Similar results are also found in Nora et al., indicating that a history of contact with the index case for more than 6 hours per day elevates the risk of childhood TB infection by eightfold.[9] Moreover, Loredo et al. corroborate these findings by establishing that the prevalence of TB in children cohabiting with ARB-positive adult TB patients ranges from 2% to 2.7%.[11]

Considering these findings, the WHO advocates for screening all children under five residing with ARB-positive adult TB patients. The recommended screening involves comprehensive measures, including tuberculin tests and chest X-rays.[12] This strategic approach aligns with the global objective of TB elimination, considering that approximately 10% of children with latent TB infection eventually manifest symptoms and signs of TB disease. This screening also emphasizes the crucial need for proactive measures in identifying and addressing latent TB infections in the pediatric population, thereby reducing TB burden and transmission.[8]

Furthermore, household density is an integral dimension influencing childhood TB incidence (OR score 9.7). The empirical data underscores a correlation between household density and elevated risk of TB. This finding corresponds with a study by Thamiris et al., who observed that there was a 25-case rise in TB incidence per 100,000 population for every additional person per household.[13] Our findings emphasize the substantial impact of housing density on TB incidence; specifically, increased household crowding exhibits a robust association with tuberculosis cases. The confined indoor environment, characterized by diminished air circulation in densely populated households, provides a conducive milieu for spreading airborne diseases like TB.

The connection between household density and TB incidence unveils a critical facet of the epidemiological landscape. The observed association noted the relevance of housing conditions in shaping the disease transmission dynamic, notably for airborne pathogens like TB. These findings accentuate the importance of targeted interventions addressing housing conditions to mitigate the risk of TB transmission. Enhancing ventilation and reducing household crowding emerge as potential strategies to disrupt the transmission chain, aligning with the broader objective of TB prevention and control. The understanding of this connection will contribute to the refinement of public health strategies tailored to the socio-environmental determinants influencing childhood TB within specific communities.[13,14]

Understanding the complex dynamics of how humidity influences tuberculosis bacteria longevity needs a comprehensive examination of environmental variables. The modulation of air humidity, contingent upon these multifarious factors, underscores the need for public health strategies considering the climatic context. Mitigating the impact of high humidity on TB transmission may involve interventions such as improved ventilation, environmental modifications, and targeted public health campaigns. Consequently, this knowledge contributes to a holistic understanding of the environmental determinants influencing the epidemiology of TB and informs the development of context-specific interventions to curb its transmission.[15]

As our study reveals, positive spatial autocorrelation is a crucial guide for informed planning and decision-making. It indicates that proximate locations share similar values and tend to form clusters. The presence of positive autocorrelation implies spatial interdependence, where the attributes of one location exert an influence on those in its neighboring vicinity. Geographical or social factors play a crucial role in fostering positive autocorrelation, leading to the clustering of similar or comparable values within specific geographical areas. These factors may include proximity, shared cultural practices, or socioeconomic conditions, contributing to the convergence of specific characteristics or behaviors within a given locale. Consequently, areas with similar geographic or social features are more likely to exhibit patterns of similarity or correlation in various phenomena, influencing the distribution and clustering of specific attributes within a region.[16,17] Rambigundam Village has the highest Moran's index, suggesting a significant clustering of positive cases sharing similar characteristics within the village and in its neighboring areas. This observation underscores the importance of understanding positive autocorrelation in guiding informed planning and decision-making endeavors. By studying the spatial patterns and their underlying factors, such as geographical proximity or shared social dynamics, stakeholders can gain valuable insights for determining interventions and resource allocation strategies. Recognizing these patterns enables a more nuanced understanding of how certain attributes or behaviors aggregate within specific locales, facilitating more effective responses tailored to local contexts. Consequently, embracing a comprehensive understanding of positive autocorrelation empowers stakeholders, including policymakers, health practitioners, and community leaders, to enact measures that address the unique needs and challenges prevalent in clustered areas, ultimately enhancing the efficacy of interventions to mitigate the spread of diseases like TB, especially in stunted children.

Identifying positive autocorrelation helps localize the patterns that may be driven by common determinants, thereby facilitating targeted interventions in specific regions. In the case of Rambigundam village, the clustering of positive cases suggests the presence of shared characteristics or conditions within the community that contribute to the observed spatial pattern. This knowledge becomes instrumental in devising strategic approaches for allocating resources, implementing interventions, and formulating policies tailored to the unique spatial dynamics of positive cases.[18,19]

In public health, understanding positive autocorrelation is vital in refining disease control strategies, especially concerning infectious diseases such as tuberculosis. The spatial insights from positive autocorrelation enable health authorities to prioritize areas with heightened risks, directing resources and efforts where they most need. This understanding of spatial patterns fosters more targeted, efficient, and impactful public health interventions for controlling and preventing diseases within specific geographic contexts.[20]

The analysis of Moran's Index in the autocorrelation test showed random results for all TB risk factors in Rambipuji District. These results mean that there is no spatial autocorrelation between TB risk factors and the incidence of childhood TB within the region. Although our results indicate randomness, it should be noted that this does not indicate the uselessness of the analysis. Instead, the random results on Moran's Index reflect the special conditions of the data used and specific geographical characteristics, where no significant spatial autocorrelation can be identified.

Several aspects can influence the interpretation of these random results. First, the relatively small sample size may be a factor that limits the ability of the analysis to provide an accurate representation of spatial autocorrelation. Only 15 children were confirmed positive for TB in this study out of 183 samples analyzed. This limited sample size may affect the ability of the analysis to detect accurate spatial patterns. In addition, certain phenomena may be random or not show significant spatial patterns. Under certain conditions, sporadic or patternless phenomena may affect the results of the spatial autocorrelation test. Therefore, careful interpretation is required, and random results do not necessarily indicate a failure of the analysis. However, they may reflect complex spatial realities and unexpected variations in the distribution of TB risk factors in the study area.

The outcomes of the NNI analysis elucidate a notably dispersed settlement pattern across all villages within the study area. This observation implies that the distribution of TB cases among children does not exhibit concentration in a localized area but instead manifests a more widespread dissemination. The findings from the NNI analysis hold relevance in the context of the broader statistical analysis, which identified specific risk factors contributing to the propagation of childhood TB. Notably, factors such as the history of close TB contact and household occupancy were identified as significant influencers on the spatial distribution of childhood TB cases. The NNI analysis method, reliant on data on the distances between settlements, is a crucial tool for discerning patterns in disease spread.

Furthermore, as reflected in the observed mean distance, the spatial analysis outcomes unveil a distinct spatial characteristic of the studied villages. Notably, only one village, Rambigundam, demonstrates an observed mean distance of less than 100 meters, indicating proximity among structures. In contrast, the remaining four villages exhibit considerable average distances, suggesting a more dispersed spatial arrangement. This spatial heterogeneity, underscored by the observed mean distances, provides valuable insights into the geographic distribution of childhood TB cases and the potential influence of settlement patterns on disease transmission dynamics.

The interplay between spatial analysis and statistical findings enhances our comprehension of the spatial epidemiology of childhood TB. The disparities in observed mean distances among villages explain the varied spatial contexts within the study area, emphasizing the need for tailored interventions based on spatial and statistical analysis. Therefore , the integration of spatial analytical techniques, such as NNI analysis, is crucial in unraveling the complexities of disease spread and elucidating the multiple interactions between environmental, demographic, and behavioral determinants in the studied communities.[5,21]

This study has some limitations. One major challenge is the limited sample size due to our limited time and human resources. This restriction poses a significant obstacle to the comprehensive understanding of the broader population. Consequently, our findings from this limited sample may be representative or reflective of the diverse characteristics of the larger populace. Moreover, specific procedures, like the tuberculin skin test, may be invasive, causing discomfort and prompting some participants to refuse participation, which might result in a biased portrayal of TB prevalence and risk factors.

CONCLUSION

The distribution of childhood TB cases among stunted children in the Rambipuji District appears to be predominantly random, except for Rambigundam Village, where cases are clustered. This suggests heightened control measures are warranted in Rambigundam Village compared to other areas. The NNI indicates that childhood TB cases among stunted children are dispersed across all villages in the Rambipuji District. Therefore, TB transmission prevention efforts, especially among stunted children, should be concentrated in all villages of the district.

CONFLICT OF INTEREST

The authors reported no potential competing interest.

ACKNOWLEDGEMENTS

We want to thank the Jember District Health Office, the village cadres and midwives who helped with field data collection, laboratory assistants, and other research assistants who helped with research data collection and processing.

AUTHOR CONTRIBUTIONS

The first author designs research methods, conducts data analysis, and makes publication manuscripts; the second author designs research methods and reviews publication manuscripts; the third author performs data analysis, interpretation of results, and makes publication manuscripts; and the fourth author performs program coding, data analysis, and interpretation of results.

LIST OF ABBREVIATIONS

ARB: Acid-Resistant Bacteria; BCG: Bacillus Calmette-Guerin; CI: Confidence Interval; EI: Estimated Index; GIS: Geographic Information System; GPS: Global Positioning System; NNI: Nearest Neighbor Index; OR: Odd Ratio; PPD: Purified Protein Derivate; SD: Standard Deviation; TB: Tuberculosis; TST: Tuberculin Skin Test; WHO: World Health Organization

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