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Nearest neighbor analysis of the spread of tuberculosis in Padang

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ABSTRACT

The rate of Tuberculosis (TB) cases in Padang has never dropped appreciably from year to year. Cases continue to be reported in all working regions of *Puskesmas* (primary healthcare center) although the precise transmission site is unknown. This study aims to determine the distribution pattern of TB sufferers in 4 Health Center working areas with the highest incidence using nearest neighbor analysis. This quantitative descriptive study used secondary data from the Padang Health Office and 4 working regions of primary healthcare centers from 2022 to March 2023, totaling 938 cases. The evidence is supported by actual observations of the physical conditions of the environment where TB patients live. The investigation of the ArcGIS program discovered that of the 4 working regions of primary healthcare centers. Mapping revealed that all locations showed a cluster pattern of TB transmission. It is hoped that these findings will be useful for health institutions in determining interventions so they can break the chain of TB transmission.

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1. INTRODUCTION

Tuberculosis (TB) is a very old disease that has persisted for hundreds of years yet has never been eradicated [1] despite social reform attempts because this medical condition is related to poor living [2]. The incidence rate and kinematic numbers for TB remain high [3], [4]. After India, Indonesia will have the biggest number of TB patients globally in 2021, followed by China, the Philippines, Pakistan, Nigeria, Bangladesh, and the Democratic Republic of the Congo. In Indonesia, the kinematic rate of TB reached 150,000 cases (one person every 4 minutes), an increase of 60% from 2020 with 93,000 kinematic cases of TB and a kinematic rate of 55 per 100,000 population. In 2021, West Sumatra Province had 8,216 cases and thus was ranked 12th out of 38 provinces. According to the Padang Health Office's P2M division, 14 working regions of primary healthcare centers had a consistently high proportion of TB patients in 2021 and 2022 [5].

Based on the results of interviews by researchers with several people in charge of pulmonary TB at the Community Health Centers in Padang City, namely the Pengambiran, Rawang and Lubuk Buaya Community Health Centers on March 18-22, 2023, a number of problems in handling pulmonary TB sufferers were revealed, namely; low compliance of patients with complete treatment, lack of awareness of pulmonary TB sufferers regarding environmental sanitation, especially the home environment so that the house is damp, the housing is crowded, so they live crowded together, then the house has minimal lighting or

ventilation, or has ventilation but is rarely opened, then there are problems The stigma never ends, so it is not uncommon for health workers to be proactive in visiting pulmonary TB sufferers at home. Based on field observations, most of these conditions occur in people who live in dense housing complexes and along the coast, such as coastal residential areas in Gates subdistrict and Teluk Bayur, Padang City.

The fundamental challenge in managing TB is the high rate of transmission, which is heavily impacted by various behavioral, social, and environmental variables. Knowledge and stigma are two behavioral issues [6]–[10] that have various impacts [11]–[14]. Stigma leads TB patients to postpone treatment, hastening the disease's spread in society. The stigmatization of TB stems from a lack of understanding of disease transmission [15], [16]. Some other impacts are physical environmental issues such as poor housing, overcrowding, and confined living conditions, which increase the risk of transmission of TB, particularly to children [17].

Smoking habits, air contamination, and lack of access to health care aggravate this illness [18], [19]. Indirect transmission can also occur by sewage workers in populations living near sewage treatment plants [20]. Social and environmental factors greatly impact disease transmission because they can enhance exposure to pathogens and susceptibility to diseases, including TB. Social environmental impacts [21], including multidimensional poverty (insufficient money, poor nutrition, inadequate education, and a lack of social support) [13], which then causes high healthcare expenses and unemployment [18].

A high disease burden caused by socio-economic issues raises the risk of TB in children [22], parents with high blood pressure and diabetes [23]–[27], aside from focusing on the transmission mechanisms, one effort that may be taken to combat TB transmission is mapping TB cases. This mapping can aid in the identification of TB hot spots, enhancing awareness of the causes of the high burden of TB and its socio-economic variables [23] as well as effective actions to prevent future transmission and tuberkulosis multidrug-resistant (MDR-TB) [28].

This study aimed to determine the distribution pattern of TB sufferers in Padang based on the work areas around the highest health centers. This is critical because disease distribution maps have previously only been created based on administrative areas such as sub-districts. A distribution map based on the working regions can assist the primary healthcare centers in knowing direct work targets and epidemiological factors of transmission, as well as planning control interventions that match potential effectively [29].

Information on the TB transmission patterns in Padang also aids in comprehending the complexities of multiple diseases and identifying susceptible locations [30] to carry out proper preventive and control procedures of multimorbidity [31]. It can also decide TB zone-based interventions [32], [33]. So, it can help break the chain of TB transmission to other communities, in addition to supporting the finding TB cases Actively, separating safely, and treating effectively (FAST) program.

2. METHOD

The descriptive quantitative approach was utilized in the study, using secondary data, namely all TB sufferers from March 2022 to March 2023, totaling 938 cases, using secondary data, namely all TB sufferers from March 2022 to March 2023, totaling 938 cases, spread across in Padang Health Office and 4 working regions of primary healthcare centers with the highest incidence of TB in Padang. The work area includes; Lubuk Buaya, Lubuk Begalung, Belimbing and Pegambiran. The data collected comes from the TB information system application/SITB at each community health center. In the ArcGIS program, Nearest Neighbor Data Analysis was used with the following formula:

$$\boldsymbol{Rn = 2D\sqrt{(n/a)}}$$

Rn is the nearest neighbor index; D is the average distance between each point and its nearest neighbor; n is the number of points under study; and a is the size of the area under study. The formula produced from the nearest-neighbour analysis produced Rn (the nearest-neighbour index), which measures the extent to which the case transmission patterns are clustered, random, or regular. Clustered was shown by an Rn-value of 0. All the dots were close to the same point. Random was indicated by an Rn-value of 1.0 without patterns. Regular was shown with an Rn-value of 2.15 with a perfectly uniform pattern where each dot is equidistant from its neighbours.

The main data that will be included in the analysis process is related to geographic location, latitude and longitude coordinate point data, size scale, it passed research ethics from the research ethics committee at Andalas Padang University, with an ethical approval number: 501/UN.16.2/KEP-FK/2023.

3. RESULTS AND DISCUSSION

Several data gathered include data on the characteristics of TB patients, the distribution pattern of TB cases based on the working regions, and the findings of the nearest-neighbour analysis.

3.1. TB Patients' characteristic

The following information acquired was about the characteristics of TB patients i.e., gender, age, occupation, and the number of cases per working region as shown in Table 1. Based on Table 2, it can be seen that most of the sufferers are men, most of the sufferers are aged between 36-55 years, do not have a job, or are unemployed, and most of them come from the Lubuk Buaya Health Center working area.

Table 1. Respondents' characteristics

Variable			n	%
Sex				
Male			647	69.0
Female			291	31.0
Age (years)*				
0–5			106	11.3
5–11			52	5.5
12–16			23	2.4
17–25			124	13.2
26–35			137	14.6
36–45			148	15.8
46–55			150	16.0
56–65			133	14.2
Over 65 years			66	7.0
Profession				
Laborer			59	6.3
Teacher/Lecturer			2	0.2
Housewife			153	16.3
Etc			24	2.6
Fisherman			19	2.0
Private employees			36	21
Student/Students			110	11.7
Retired			1	0.1
Farmers/Ranchers/Fishermen			3	0.3
civil servants			7	0.7
Driver			10	1.1
Doesn't work			297	31.7
Not known			1	0.1
Correctional inmates			4	0.4
Self-employed			230	24.5
Primary healthcare center's	In region		Outside the region	
	n	%	n	%
Belimbing	231	25.44	6	20.00
Lubuk Begalung	260	28.63	3	10.00
Lubuk Buaya	302	33.26	20	66.67
Pegambiran	115	12.67	1	5.33
Total	908	100	30	100

*Age categories according to the Indonesian Ministry of Health in 2009

3.2. Nearest-neighbor analysis

The following are the results of the nearest-neighbor analysis from the four research areas. According to Table 2, most of the distribution patterns of TB cases in the working regions analyzed are in groups or clusters. In contrast, the remaining three working regions showed random distribution patterns.

Table 2. Average nearest-neighbor analysis

Working regions of primary healthcare center	Nearest neighbor ratio	z-score	p-value	Distribution patterns
Belimbing	0.728342	-7.915840	0.000000	Cluster
Lubuk Begalung	0.619371	-11.76393	0.000000	Cluster
Lubuk Buaya	0.581279	-14.01253	0.000000	Cluster
Pegambiran	0.519847	-9.893266	0.000000	Cluster

3.3. The distribution of TB cases

The distribution pattern of TB cases in the Primary Healthcare Center's 4 operating regions will be explained based on each region's demographic parameters. This aims to facilitate understanding of the pattern of TB spread in the region. Based on Table 2, it can be seen that the results of the nearest neighbor analysis found that the pattern of TB distribution in the work area of the community health center was a cluster. A brief description of the distribution of TB cases based on Primary Healthcare Center's work area is as:

3.3.1. Belimbing's working regions

Belimbing's working regions are heavily inhabited and relatively extensive, consisting of hilly terrain, agricultural land, and plantations. These neighborhoods have various dense housing developments and public services like marketplaces facing the Ambacang, Kuranji, Nanggalo, Tunggul Hitam, and Air Dingin Primary Healthcare Centers. There are various residential zones in this area as presented in Figure 1. With 231 cases, these regions were ranked third in the country, with six cases originating from outside the regions. The mapping results revealed 69 TB patients in groups or clusters, of which six cases were originating outside the regions. According to the map, there are multiple cases in heavily populated residential neighborhoods and public marketplaces of these regions. Case transfer is possible because of transmission from nearby locations such as Air Dingin, Ambacang, and Kuranji.

3.3.2. Lubuk Begalung's working regions

Lubuk Begalung's working regions are both heavily inhabited and industrial. They have several dense housing complexes and public services such as marketplaces surrounding the Pegambiran, Rawang, Pauh, and Andalas medical centers. There are several residential neighborhoods in this area as shown in Figure 2. With 260 cases, of which three cases were originating outside the regions. The regions had the second largest number of cases, with six cases coming from outside the regions. The map shows that the clusters are quite dense and occur within each other. This situation may be seen in several housing and community settlements throughout sub-districts.

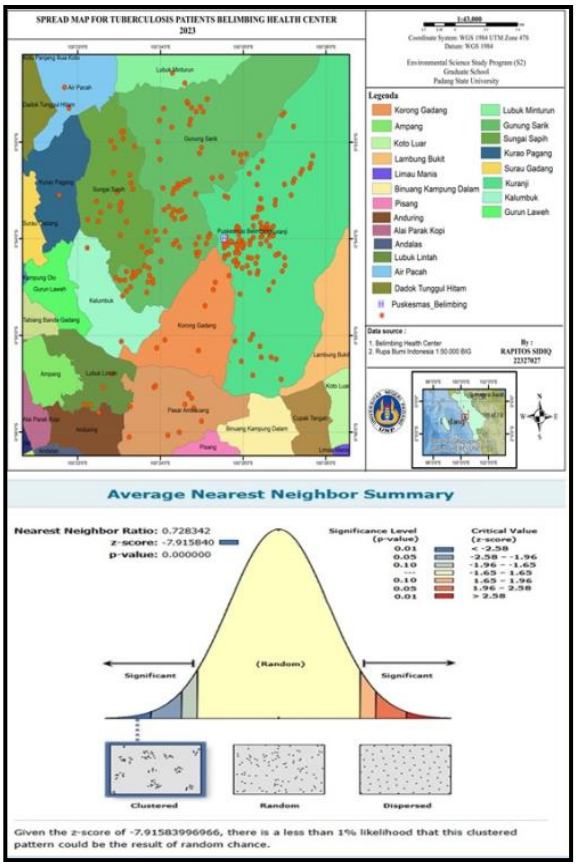

Figure 1. Working regions of Belimbing

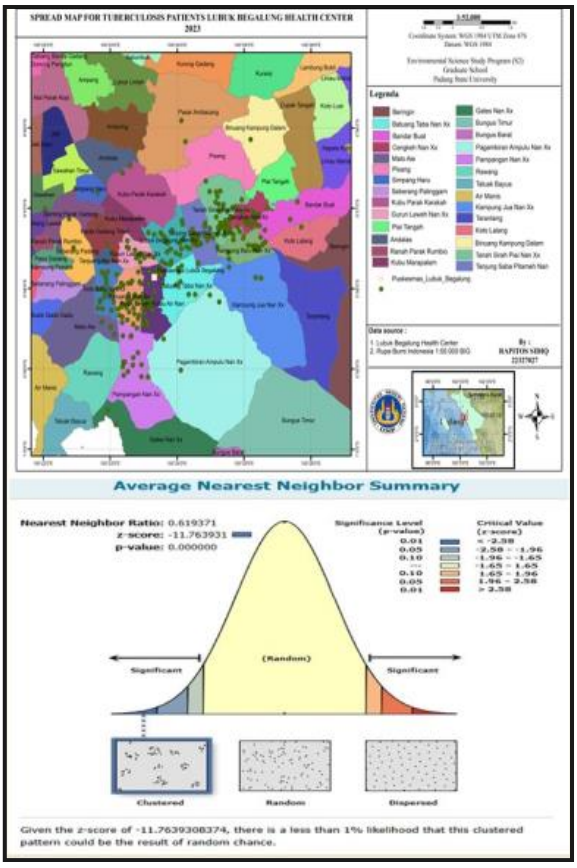

Figure 2. Working regions of Lubuk Begalung

3.3.3. Lubuk buaya's working regions

Lubuk Buaya's working regions are highly inhabited, located in a very densely populated coastal area with inadequate environmental sanitation as shown in Figure 3. The regions share borders with Anak Air Tawar's working areas. They had the most cases in Padang, with 302 cases, of which 20 cases were originating outside the regions. The mapping results showed TB in groups or clusters. The map shows many cases in this location. Several clusters of diseases have been reported in densely populated regions and along the shore. The transmission of this disease is most likely linked to the nearby working area, notably Anak Air.

3.3.4. Pegambiran's working regions

Pegambiran's working regions are heavily inhabited and extensive, consisting of hilly terrain, agricultural land, and rubber processing companies. This region has various public services, including marketplaces, the Teluk Bayur port, and train transportation. Multiple dense housing also adjoins Lubuk Begalung, Rawang, and Pauh Primary Healthcare Centers. There are several residential neighborhoods in these areas as shown in Figure 4. With 115 cases, the regions were ranked fourth in the country, with one case originating outside the regions. The mapping results revealed group or cluster TB cases. According to the map, several clusters of cases occurred in various dense communities surrounding the primary healthcare centres and on the edges of roads and ports. The case group was near Lubuk Begalung's and Rawang's working regions.

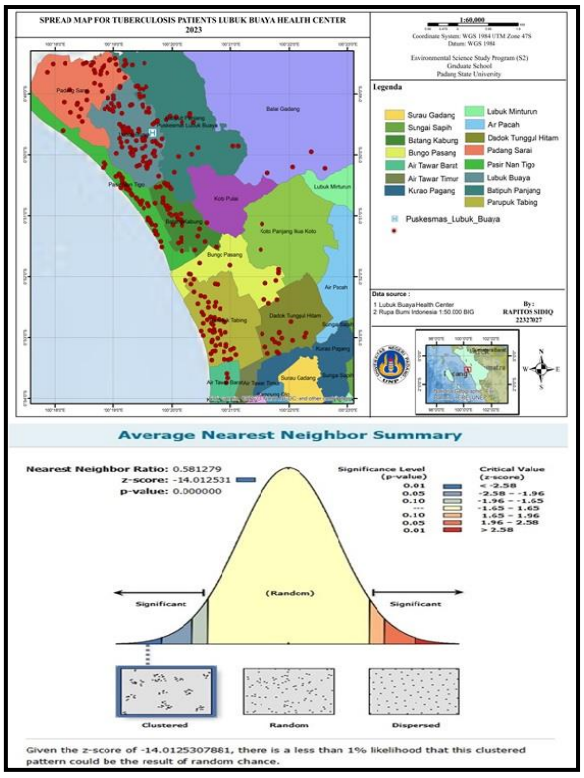

Figure 3. Working regions of Lubuk Buaya

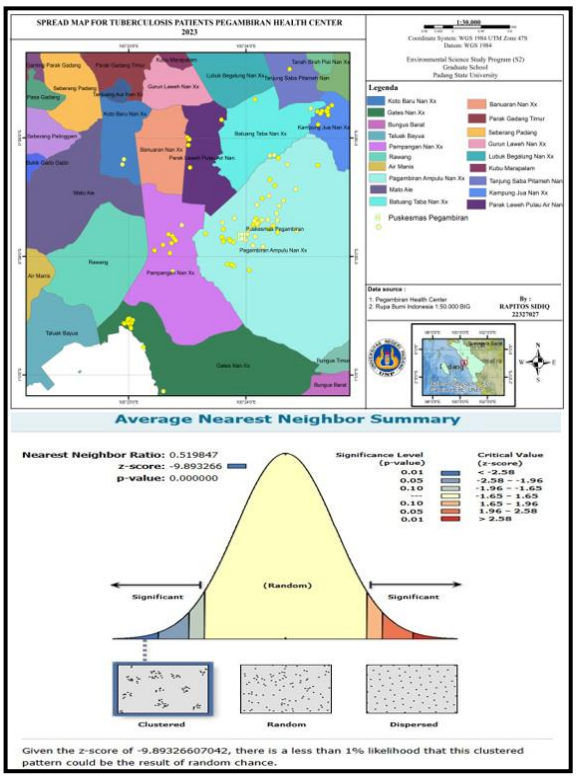

Figure 4. Working regions of Pegambiran

The total case rate was relatively high in numerous working regions of primary healthcare centers in Padang. This is inextricably linked to its extremely diverse state, which causes the high transmission of TB in urban areas [34]. The study discovered an overview of the distribution of TB patients in numerous zones of healthcare facilities in Padang. Generally, the distribution of TB cases in Padang is classified as clusters or random. The distribution of TB cases in these four regions is classified as a cluster. If we look closely, the majority of cluster distribution occurs in locations where there are many cases. Cluster patterns of disease transmission are common across time in big populations.

Looking closely at the findings of this mapping, we can see that the pattern of distribution and growth in cases happens in highly populated residential areas, such as the working regions of Lubuk Buaya,

Lubuk Begalung, Pegambiran, and Belimbing. Cases in the areas spread in clusters and significant numbers. Regional distance causes group cases to emerge. The environment in which an individual resides and their actions significantly impact the spread of TB. These two things are linked. This means the disease spreads from members to others in close distance or in the same house. A crowded household environment is associated with inadequate air circulation and lighting, increasing the spread of TB [35], especially among residents who smoke [36]. If an individual wishes to limit the incidence and spread of tuberculosis, you must address the problem of smoking.

Exposure to cigarette smoke is frequent in places with a high frequency of tuberculosis. Cigarette smoke has a complicated and multifaceted influence on lung immunity against tuberculosis infection from [36], [37] poor physical condition of the house, such as walls, ventilation, and temperature [38], [39]. Then, exposure to smoking, population density [34], and poor home circumstances are linked to the prevalence of TB, particularly in adolescents [40].

The greater the percentage of people living in detrimental housing, the higher the prevalence of TB. This suggests that the physical environment of the house, as a sign of a healthy home, is intimately associated with the transmission of TB [41]. Interaction or contact pattern with TB patients at home needs special consideration [42]. The patterns and length of long-term social interaction are more significant in this scenario than the quantity of encounters [41], [43], [44].

Population density has an impact [45], another study discovered that one in every 30 household contacts will get active TB [46]. As a result, measures to prevent TB among family members are extremely successful, and failure to perform contact investigations will result in a significant burden of disease and mortality in the future [47]. This is, of course, inextricably linked to extremely poor socio-economic difficulties [48], more than 31% of TB patients observed in this study did not work or were jobless; however, their age and gender are unknown. According to the findings of mapping and observation, low socio-economic community settlements are located along the coast, such as the Pengambiran and Rawang, working regions, as well as mining areas [30] such as the Pengambiran and Lubuk Begalung area, which is the industrial area of Semen Padang, one of Indonesia's largest cement companies. This is aggravated by the cement factory's dust, which raises the risk of TB [49].

The age element, particularly in children, significantly impacts transmission through interaction [48], [50]. Babies and toddlers are more vulnerable to infection than adults with TB [51]. According to this study, more than 18% of TB cases were detected in adolescents (0-16 years old), and more than 69% of victims were male. Men bear a heavier load, which has ramifications for population transmission [52].

The disease has a significant impact on the rate of transmission to newborns and children. As a result, extensive preventive interventions are desperately needed, particularly in populations with a high prevalence of TB, to reduce the risk of disease in children under five [51], so that efforts to strengthen decentralized services in health and community service facilities must be made [53]. Aside from that, the disease's burden has highly unfavorable implications for growth and development because it mostly affects individuals of productive age [54]. Most patients are between the ages of 17 and 65 years.

Aside from that, the high degree of urbanization and the high prevalence of TB significantly impact the spread of TB [55]. In this instance, Padang is a major city with a high population and level of urbanization. Climate change has an impact on transmission in a variety of ways. Aside from that, mountains such as Lubuk Kilangan, Air Dingin, Belimbing, and wetland regions are extremely sensitive to climate change and exposure to air pollution, putting TB development in danger [56], [57]. This condition influences individual heterogeneity and is critical in transmitting tuberculosis in subpopulations [34].

Community behaviors, such as gathering patterns, also impact TB transmission. Therefore, TB patients require physical intervention, such as wearing masks, reducing physical distance, restricting mass meetings, or forbidding patients from mingling with crowds [58]. It is vital to consider a TB control program that focuses on density-control techniques, particularly in high-incidence regions [13] and that address the issue of stigma [9], [59], as well as poor information and attitudes concerning TB [60], effective contact screening [61], offers preventative treatment to all home contacts [62], improves housing quality [63], aids in overcoming the problem of TB patients struggling to reach health facilities [64]. As a result, efforts must be made to provide social support and health education, which will influence patient compliance to finish treatment [65], housing affordability multi-sectoral public health intervention [66]. To do everything, involve all parties, especially community leaders, in terms of increasing awareness of disease and overcoming stigma problems, especially in rural areas [67]. A follow-up to the findings of this research is a control strategy for environmental and behavioral factors that are risk factors for the spread of TB, especially in areas with a high incidence.

4. CONCLUSION

The spread of TB cases in 4 community health centers of working areas in Padang occurred in cluster. These findings have important implications, both in terms of epidemiology, public health and health policy. As a basis for knowing indications of significant sources of infection in a particular community or environment. This allows health workers to focus more on identifying and controlling the source of the infection. Clustering can also help in contact tracing and implementing more effective quarantine measures. Indicates that there is an increased risk of transmission in certain groups or populations, requiring special interventions to reduce the risk of transmission in that group. Cluster distribution requires a more focused and intensive allocation of health resources in the affected areas or groups. This could involve sending medical personnel, diagnostic equipment, and medicines to the area. Opportunities to increase outreach and education efforts to the public regarding prevention methods, symptoms and the importance of early detection. This could also include vaccination campaigns and hygiene promotion. It can be used to evaluate the effectiveness of existing health policies and adjust them to be more responsive to disease spread patterns. The cluster spread of TB has significant social and economic impacts, including social stigma towards infected individuals, disruption to local economic activities, and increased health costs.

REFERENCES

[1] M. Coleman, L. Martinez, G. Theron, R. Wood, and B. Marais, "Mycobacterium tuberculosis transmission in high-incidence settings-new paradigms and insights," *Pathogens*, vol. 11, no. 11, 2022, doi: 10.3390/pathogens11111228.

[2] M. Y. G. S. Freitas *et al.*, "Socioeconomic context in Brazil and tuberculosis risk factors: what has changed?," *International Journal of Health Science*, vol. 2, no. 12, pp. 2–9, Feb. 2022, doi: 10.22533/at.ed.1592122223023.

[3] A. Khanna, R. Saha, and N. Ahmad, "National TB elimination programme-what has changed," *Indian Journal of Medical Microbiology*, no. October, 2022, doi: 10.1016/j.ijmmb.2022.10.008.

[4] Global Tuberculosis Programme, *Global tuberculosis report*, vol. 21, no. 1. World Health Organization, 2020. [Online]. Available: https://www.who.int/publications/i/item/9789240013131

[5] Padang Health Office's P2M division, "Padang city health profile in 2022," Padang, 2023. [Online]. Available: https://dinkes.padang.go.id/profil-kesehatan-kota-padang-tahun-2022-1254

[6] M. Mohammedhussein, M. Hajure, J. E. Shifa, and T. A. Hassen, "Perceived stigma among patient with pulmonary tuberculosis at public health facilities in southwest Ethiopia: a cross-sectional study," *PLoS ONE*, vol. 15, no. 12 December, 2020, doi: 10.1371/journal.pone.0243433.

[7] D. DeSanto *et al.*, "A qualitative exploration into the presence of TB stigmatization across three districts in South Africa," *BMC Public Health*, vol. 23, no. 1, 2023, doi: 10.1186/s12889-023-15407-2.

[8] E. Wouters *et al.*, "How the HIV/TB co-epidemic-HIV stigma-TB stigma' syndemic impacts on the use of occupational health services for TB in South African hospitals: a structural equation modelling analysis of the baseline data from the HaTSaH study (cluster RCT)," *BMJ Open*, vol. 12, no. 4, 2022, doi: 10.1136/bmjopen-2020-045477.

[9] A. Daftary, E. M. H. Mitchell, M. J. A. Reid, E. Fekadu, and E. Goosby, "To end TB, first-ever high-level meeting on tuberculosis must address stigma," *American Journal of Tropical Medicine and Hygiene*, vol. 99, no. 5, pp. 1114–1116, 2018, doi: 10.4269/ajtmh.18-0591.

[10] G. W. Mbuthia, H. D. N. Nyamogoba, S. S. Chiang, and S. T. McGarvey, "Burden of stigma among tuberculosis patients in a pastoralist community in Kenya: a mixed methods study," *PLoS ONE*, vol. 15, no. 10 October, 2020, doi: 10.1371/journal.pone.0240457.

[11] C. Bolster-Foucault, B. H. M. Fane, and A. Blair, "Structural determinants of stigma across health and social conditions: a rapid review and conceptual framework to guide future research and intervention," *Health Promotion and Chronic Disease Prevention in Canada*, vol. 41, no. 3, pp. 85–115, 2021, doi: 10.24095/HPCDP.41.3.03.

[12] A. O. Bashorun *et al.*, "Knowledge, attitude and practice towards tuberculosis in Gambia: a nation-wide cross-sectional survey," *BMC Public Health*, vol. 20, no. 1, 2020, doi: 10.1186/s12889-020-09685-3.

[13] X. Chen *et al.*, "Tuberculosis-related stigma and its determinants in Dalian, Northeast China: a cross-sectional study," *BMC Public Health*, vol. 21, no. 1, 2021, doi: 10.1186/s12889-020-10055-2.

[14] A. Medina-Marino *et al.*, "Qualitative identification of intervention preferences to support men's engagement and retention in TB care in South Africa," *American Journal of Men's Health*, vol. 16, no. 5, 2022, doi: 10.1177/15579883221129349.

[15] I. V. Kolte, L. Pereira, A. Benites, I. M. C. De Sousa, and P. C. Basta, "The contribution of stigma to the transmission and treatment of tuberculosis in a hyperendemic indigenous population in Brazil," *PLoS ONE*, vol. 15, no. 12 December, 2020, doi: 10.1371/journal.pone.0243988.

[16] O. Nkereuwem *et al.*, "Perspectives of TB survivors and policymakers on post-TB disability," *Public Health Action*, vol. 13, no. 1, pp. 17–22, Mar. 2023, doi: 10.5588/pha.22.0050.

[17] S. Kim *et al.*, "High prevalence of tuberculosis infection and disease in child household contacts of adults with rifampin-resistant tuberculosis," *Pediatric Infectious Disease Journal*, vol. 41, no. 5, pp. e194–e202, May 2022, doi: 10.1097/INF.0000000000003505.

[18] M. Najafizada, A. Rahman, Q. Taufique, and A. Sarkar, "Social determinants of multidrug-resistant tuberculosis: a scoping review and research gaps," *Indian Journal of Tuberculosis*, vol. 68, no. 1, pp. 99–105, 2021, doi: 10.1016/j.ijtb.2020.09.016.

[19] X. Wang and Y. Cai, "The influence of ambient air pollution on the transmission of tuberculosis in Jiangsu, China," *Infectious Disease Modelling*, vol. 8, no. 2, pp. 390–402, Jun. 2023, doi: 10.1016/j.idm.2023.03.003.

[20] H. N. Mtetwa, I. D. Amoah, S. Kumari, F. Bux, and P. Reddy, "The source and fate of Mycobacterium tuberculosis complex in wastewater and possible routes of transmission," *BMC Public Health*, vol. 22, no. 1, 2022, doi: 10.1186/s12889-022-12527-z.

[21] G. A. Noppert, S. T. Hegde, and J. T. Kubale, "Practice of epidemiology exposure, susceptibility , and recovery: a framework for examining the risk," *American Journal of Epidemiology*, vol. 192, no. 3, pp. 475–482, 2022.

[22] D. W. S. R. Wardani and E. P. Wahono, "Socio-economic position as risk factor of childhood tuberculosis," in *E3S Web of Conferences*, T. R. Soeprobowati, B. Warsito, and T. Triadi Putranto, Eds., Nov. 2021, p. 01036. doi: 10.1051/e3sconf/202131701036.

[23] F. A. Mphande-Nyasulu, P. Puengpipattrakul, M. Praipruksaphan, A. Keeree, and K. Ruanngean, "Prevalence of tuberculosis (TB), including multi-drug-resistant and extensively-drug-resistant TB, and association with occupation in adults at Sirindhorn Hospital, Bangkok," *IJID Regions*, vol. 2, pp. 141–148, 2022, doi: 10.1016/j.ijregi.2022.01.004.
[24] M. do S. N. Evangelista, R. Maia, J. P. Toledo, R. G. de Abreu, and D. Barreira, "Tuberculosis associated with diabetes mellitus by age group in Brazil: a retrospective cohort study, 2007–2014," *Brazilian Journal of Infectious Diseases*, vol. 24, no. 2, pp. 130–136, 2020, doi: 10.1016/j.bjid.2020.03.005.
[25] U. Abbas *et al.*, "Tuberculosis and diabetes mellitus: relating immune impact of co-morbidity with challenges in disease management in high burden countries," *Journal of Clinical Tuberculosis and Other Mycobacterial Diseases*, vol. 29, 2022, doi: 10.1016/j.jctube.2022.100343.
[26] V. Mave *et al.*, "Diabetes mellitus and tuberculosis treatment outcomes in Pune, India," *Open Forum Infectious Diseases*, vol. 8, no. 4, pp. 1–8, 2021, doi: 10.1093/ofid/ofab097.
[27] I. S. Pradipta, L. D. Forsman, J. Bruchfeld, E. Hak, and J. W. Alffenaar, "Risk factors of multidrug-resistant tuberculosis: a global systematic review and meta-analysis," *Journal of Infection*, vol. 77, no. 6, pp. 469–478, 2018, doi: 10.1016/j.jinf.2018.10.004.
[28] Y. Xi, W. Zhang, R. J. Qiao, and J. Tang, "Risk factors for multidrug-resistant tuberculosis: a worldwide systematic review and meta-analysis," *PLoS ONE*, vol. 17, no. 6 June, 2022, doi: 10.1371/journal.pone.0270003.
[29] O. J. Daniel, O. A. Adejumo, A. D. Alabi, J. O. Bamidele, and K. S. Oritogun, "Spatial analysis of tuberculosis and risk factors at the lowest administrative level in Nigeria," *African Journal of Health Sciences*, vol. 35, no. 1, pp. 70–82, 2022.
[30] I. Gwitira, N. Karumazondo, M. D. Shekede, C. Sandy, N. Siziba, and J. Chirenda, "Spatial patterns of pulmonary tuberculosis (TB) cases in Zimbabwe from 2015 to 2018," *PLoS ONE*, vol. 16, no. 4 April, 2021, doi: 10.1371/journal.pone.0249523.
[31] B. Hernández *et al.*, "Comparisons of disease cluster patterns, prevalence and health factors in the USA, Canada, England and Ireland," *BMC Public Health*, vol. 21, no. 1, 2021, doi: 10.1186/s12889-021-11706-8.
[32] M. B. Brooks *et al.*, "Mapping local hot spots with routine tuberculosis data: a pragmatic approach to identify spatial variability," *PLoS ONE*, vol. 17, no. 3 March, 2022, doi: 10.1371/journal.pone.0265826.
[33] I. G. N. E. Putra, M. Rahmaniati, T. Sipahutar, and T. Eryando, "Modeling the prevalence of tuberculosis in Java, Indonesia: an ecological study using geographically weighted regression," *Journal of Population and Social Studies*, vol. 30, pp. 741–763, 2022, doi: 10.25133/JPSSv302022.041.
[34] J. P. Smith *et al.*, "Characterizing tuberculosis transmission dynamics in high-burden urban and rural settings," *Scientific Reports*, vol. 12, no. 1, 2022, doi: 10.1038/s41598-022-10488-2.
[35] Lili Amaliah, Arie Ardiyanti Rufaedah, Sri Nurcahyati, R. Nur Abdurakhman, and Abas Hidayat, "The relationship between the physical home environment and the event of tuberculosis," *World Journal of Advanced Research and Reviews*, vol. 14, no. 3, pp. 623–628, Jun. 2022, doi: 10.30574/wjarr.2022.14.3.0627.
[36] D. H. Quan, A. J. Kwong, P. M. Hansbro, and W. J. Britton, "No smoke without fire: the impact of cigarette smoking on the immune control of tuberculosis," *European Respiratory Review*, vol. 31, no. 164, 2022, doi: 10.1183/16000617.0252-2021.
[37] W. Wang *et al.*, "The burden and predictors of latent tuberculosis infection among elder adults in high epidemic rural area of tuberculosis in Zhejiang, China," *Frontiers in Cellular and Infection Microbiology*, vol. 12, 2022, doi: 10.3389/fcimb.2022.990197.
[38] E. E. Amiruddin and N. Meilani, "Analysis of the relationship between the physical conditions of the house , smoking and the incidence of pulmonary tuberculosis in Central Buton," *International Journal of Scientific Multidisciplinary Research (IJSMR)*, vol. 1, no. 5, pp. 361–374, 2023.
[39] R. J. Siregar, S. F. Yusuf, and D. Fernaldy, "The relationship between physical conditions of the house and the incidence of tuberculosis," *International Journal of Public Health Excellence (IJPHE)*, vol. 1, no. 1, pp. 01–05, 2022, doi: 10.55299/ijphe.v1i1.2.
[40] N. Siddalingaiah, K. Chawla, S. B. Nagaraja, and D. Hazra, "Risk factors for the development of tuberculosis among the pediatric population: a systematic review and meta-analysis," *European Journal of Pediatrics*, pp. 3007–3019, 2023, doi: 10.1007/s00431-023-04988-0.
[41] M. Musfirah, D. Nurfita, and A. F. Rangkuti, "Analysis of healthy housing and TB prevalence in Yogyakarta City," *Jurnal Kesehatan Masyarakat*, vol. 17, no. 3, pp. 405–414, Mar. 2022, doi: 10.15294/kemas.v17i3.28692.
[42] M. Li *et al.*, "High proportion of tuberculosis transmission among social contacts in rural China: a 12-year prospective population-based genomic epidemiological study," *Emerging Microbes and Infections*, vol. 11, no. 1, pp. 2102–2111, 2022, doi: 10.1080/22221751.2022.2112912.
[43] N. Amoori, B. Cheraghian, P. Amini, and S. M. Alavi, "Social contact patterns associated with tuberculosis: a case-control study in Southwest Iran," *Journal of Preventive Medicine and Public Health*, vol. 55, no. 5, pp. 485–491, 2022, doi: 10.3961/jpmph.22.335.
[44] J. C. Emery *et al.*, "Estimating the contribution of subclinical tuberculosis disease to transmission: an individual patient data analysis from prevalence surveys," *eLife*, vol. 12, p. 2022.06.09.22276188, 2023, doi: 10.7554/eLife.82469.
[45] D. L. Yang *et al.*, "Spatial analysis and influencing factors of pulmonary tuberculosis among students in Nanning, during 2012–2018," *PLoS ONE*, vol. 17, no. 5 May, 2022, doi: 10.1371/journal.pone.0268472.
[46] G. Seid, A. Alemu, B. Dagne, W. Sinshaw, and B. Gumi, "Tuberculosis in household contacts of tuberculosis patients in sub-Saharan African countries: a systematic review and meta-analysis," *Journal of Clinical Tuberculosis and Other Mycobacterial Diseases*, vol. 29, 2022, doi: 10.1016/j.jctube.2022.100337.
[47] T. Ryckman *et al.*, "Impact and cost-effectiveness of short-course tuberculosis preventive treatment for household contacts and people with HIV in 29 high-incidence countries: a modelling analysis," *The Lancet Global Health*, vol. 11, no. 8, pp. e1205–e1216, 2023, doi: 10.1016/S2214-109X(23)00251-6.
[48] S. Atkins *et al.*, "The socioeconomic impact of tuberculosis on children and adolescents: a scoping review and conceptual framework," *BMC Public Health*, vol. 22, no. 1, 2022, doi: 10.1186/s12889-022-14579-7.
[49] P. Jamshidi *et al.*, "Silicosis and tuberculosis: a systematic review and meta-analysis," *Pulmonology*, Jun. 2023, doi: 10.1016/j.pulmoe.2023.05.001.
[50] A. Dey, I. Roy, A. K. Chakrabartty, A. Choudhury, and A. Lahiri, "Changing patterns of household transmission of tuberculosis in an eastern state of India: the impact of COVID19 pandemic," *Indian Journal of Tuberculosis*, vol. 69, no. 4, pp. 682–689, 2022, doi: 10.1016/j.ijtb.2022.03.001.
[51] L. Martinez *et al.*, "The risk of tuberculosis in children after close exposure: a systematic review and individual-participant meta-analysis," *The Lancet*, vol. 395, no. 10228, pp. 973–984, 2020, doi: 10.1016/S0140-6736(20)30166-5.
[52] K. C. Horton, A. L. Hoey, G. Béraud, E. L. Corbett, and R. G. White, "Systematic review and meta-analysis of sex differences in social contact patterns and implications for tuberculosis transmission and control," *Emerging Infectious Diseases*, vol. 26, no. 5, pp. 910–919, 2020, doi: 10.3201/eid2605.190574.
[53] C. M. Yuen *et al.*, "Tuberculosis care models for children and adolescents: a scoping review," *Bulletin of the World Health Organization*, vol. 100, no. 12, pp. 777-788L, 2022, doi: 10.2471/BLT.22.288447.
[54] F. R. Adewoyin, A. Ogunkorode, O. A. Akpor, and A. M. Ayorinde, "Burden of tuberculosis in Nigeria: self care strategies and

prevention of complication," *Euro Afro Studies International Journal*, vol. 4, no. 4, pp. 1–13, 2022.
[55] H. Ren, W. Lu, X. Li, and H. Shen, "Specific urban units identified in tuberculosis epidemic using a geographical detector in Guangzhou, China," *Infectious Diseases of Poverty*, vol. 11, no. 1, 2022, doi: 10.1186/s40249-022-00967-z.
[56] H. Li, M. Ge, and M. Zhang, "Spatio-temporal distribution of tuberculosis and the effects of environmental factors in China," *BMC Infectious Diseases*, vol. 22, no. 1, 2022, doi: 10.1186/s12879-022-07539-4.
[57] S. Kharwadkar, V. Attanayake, J. Duncan, N. Navaratne, and J. Benson, "The impact of climate change on the risk factors for tuberculosis: a systematic review," *Environmental Research*, vol. Volume 212, 2023, doi: 10.1016/j.envres.2022.113436.
[58] T. Jefferson *et al.*, "Physical interventions to interrupt or reduce the spread of respiratory viruses," *Cochrane Database of Systematic Reviews*, vol. 2020, no. 11, pp. 311–312, Nov. 2020, doi: 10.1002/14651858.CD006207.pub5.
[59] A. K. Jing Teo *et al.*, "Characterizing and measuring tuberculosis stigma in the community: a mixed-methods study in Cambodia," *Open Forum Infectious Diseases*, vol. 7, no. 10, 2020, doi: 10.1093/ofid/ofaa422.
[60] M. Vericat-Ferrer *et al.*, "Knowledge, attitudes, and stigma: the perceptions of tuberculosis in equatorial guinea," *International Journal of Environmental Research and Public Health*, vol. 19, no. 14, 2022, doi: 10.3390/ijerph19148227.
[61] S. Naresh, M. Sharma, V. Singh, B. K. Anand, P. Verma, and M. P. S. Marwaha, "Household symptomatic contact screening of sputum smear positive tuberculosis patients at the DOTS clinic of SGT hospital, Gurugram," *Indian Journal of Community Health*, vol. 34, no. 4, pp. 521–524, 2022, doi: 10.47203/IJCH.2022.v34i04.013.
[62] C. M. Yuen, J. A. Seddon, S. Keshavjee, and P. J. Dodd, "Risk-benefit analysis of tuberculosis infection testing for household contact management in high-burden countries: a mathematical modelling study," *The Lancet Global Health*, vol. 8, no. 5, pp. e672–e680, 2020, doi: 10.1016/S2214-109X(20)30075-9.
[63] J. Y. Lee, N. Kwon, G. yeon Goo, and S. il Cho, "Inadequate housing and pulmonary tuberculosis: a systematic review," *BMC Public Health*, vol. 22, no. 1, pp. 1–12, 2022, doi: 10.1186/s12889-022-12879-6.
[64] P. Makeswaran, S. A. Shah, N. Safian, N. A. Muhamad, and A. A. Harith, "Determinants of delayed tuberculosis treatment among patients in Selangor: a study protocol," *PLoS ONE*, vol. 17, no. 4 April, pp. 1–11, 2022, doi: 10.1371/journal.pone.0266746.
[65] D. Dilas *et al.*, "Social support, quality of care, and patient adherence to tuberculosis treatment in Peru: the mediating role of nurse health education," *Patient Preference and Adherence*, vol. 17, pp. 175–186, 2023, doi: 10.2147/PPA.S391930.
[66] N. Ortiz-ruiz, D. Zamudio-espinosa, M. Satizabal-reyes, and L. C. Luna-miranda, "Social vulnerability and tuberculosis: a vicious circle Social vulnerability and tuberculosis: a vicious circle," *Entramado*, vol. 9, no. 1, pp. 0–19, 2023.
[67] D. A. Oladele *et al.*, "'Their place is beyond the town's border': a qualitative exploration of stigma associated with tuberculosis in rural and urban areas of Lagos, Nigeria," *Health and Social Care in the Community*, vol. 29, no. 6, pp. 1789–1798, 2021, doi: 10.1111/hsc.13287.

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