

Trend and Correlation Between the Scope of Tuberculosis Preventive Therapy (TPT) and Treatment Success Rate (TSR) with the Case Notification Rate (CNR) of Tuberculosis in Indonesia During 2021-2023

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Article Info

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Submitted: 28-07-2025

Accepted: 24-11-2025

Published: 01-12-2025

Citation:

Baiti, N., Wahjuni, C. U., & Artanti, K. D. (2025). Trend and Correlation Between the Scope of Tuberculosis Preventive Therapy (TPT) and Treatment Success Rate (TSR) with the Case Notification Rate (CNR) of Tuberculosis in Indonesia During 2021-2023. *Media Gizi Kesmas*, 14(2), 294-302.

<https://doi.org/10.20473/mgk.v14i2.2025.294-302>

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ABSTRACT

Background: Tuberculosis remains a major public health problem in Indonesian. The Indonesian TB control program for the 2020–2024 period aims to accelerate the achievement of national TB elimination by 2030 and contribute to ending the global TB epidemic by 2050, aligning with the WHO's End TB Strategy. As part of this national strategy, the government has implemented various interventions, including the provision of Tuberculosis Preventive Therapy (TPT) to high-risk groups and improvements in the Treatment Success Rate (TSR).

Objectives: This research aims to analyze the trends and the correlation between TPT and TSR with the incidence of tuberculosis, measured through the Case Notification Rate (CNR) at the provincial level during 2021-2023.

Methods: This research is an ecological study using quantitative methods. The data in this research are based on tuberculosis prevention reports from the Directorate of Disease Prevention and Control, Ministry of Health of Indonesia, from 2021 to 2023. The variables analyzed in this research are TPT coverage and TSR with CNR in 2021-2023.

Results: The study results show an increasing trend in CNR in Indonesian provinces for three consecutive years. Furthermore, TPT coverage has also increased, although it remains relatively low, and TSR shows variation across provinces. Spearman's analysis indicates a correlation between TPT, TSR, and CNR. However, the correlations are weak and mostly negative.

Conclusion: TPT coverage and TSR in Indonesia showed improvement during 2021–2023, although disparities remained between provinces. The weak correlations between TPT, TSR, and incidence rates indicate that prevention and treatment interventions have not yet fully impacted the reduction of new cases. Strengthening case detection, enhancing contact tracing, and expanding TPT are needed to accelerate the decline in TB incidence nationally.

Keywords: CNR, TPT, TSR, Tuberculosis

INTRODUCTION

Tuberculosis (TB) is an infectious disease caused by *Mycobacterium tuberculosis*, which primarily attacks the lungs but can also infect other organs such as the lymph nodes, bones, kidneys, and brain (WHO, 2023). Indonesia is estimated to have around 1.08 million TB cases, contributing

approximately 10% of global TB cases and ranking as the country with the second-highest TB burden after India (WHO, 2023). Based on data from the Indonesian Ministry of Health, TB incidence in 2023 was estimated at 387 per 100,000 population, indicating that TB remains a major public health concern and is included in Sustainable Development

Goals (SDGs) Target 3.3, which aims to end the epidemic of major infectious diseases, including TB (Kemenkes RI, 2023; United Nations, 2023). The Indonesian TB control program for the 2020–2024 period aims to accelerate national TB elimination by 2030 and contribute to ending the global TB epidemic by 2050, aligning with the WHO End TB Strategy (Kemenkes RI, 2020). As part of this strategy, the government has implemented various interventions, including the expansion of Tuberculosis Preventive Therapy (TPT) for high-risk groups and the improvements in the Treatment Success Rate (TSR) (Kemenkes RI, 2021a; Kemenkes RI, 2021b). TPT prevents latent TB infection from progressing into active disease, especially among household contacts and people living with HIV (WHO, 2020), while TSR reflects the quality of TB treatment services, with a national minimum target of 90% (Kemenkes RI, 2020). With increased TPT coverage and high TSR performance, Indonesia aims to reduce its TB burden and move closer to elimination targets.

Despite longstanding control efforts, TB incidence in Indonesia remains high and exhibits substantial regional disparities in program outcomes. While WHO sets the minimum TSR at 90%, national and provincial results vary, and TPT coverage, though improving, remains below optimal levels (WHO, 2023; Kemenkes RI, 2023). Indonesia accounts for about 10% of global TB cases, ranking second worldwide after India. In 2023, Indonesia recorded an estimated 1.09 million TB cases (387 per 100,000 population), with 821,200 reported (74%), leaving 26% unnotified. TB-related deaths decreased by 7% from 2022, but MDR/RR-TB detection remained at only 51% of estimated cases (WHO, 2023). Globally, the WHO End TB Strategy targets an 80% reduction in TB incidence and a 90% reduction in TB deaths by 2030 compared with 2015 (WHO, 2015). Indonesia's National TB Elimination Roadmap aligns with these targets, aiming for a reduction of TB incidence to 65 per 100,000 population and a 90% decrease in TB mortality by 2030 (Kemenkes RI, 2020). However, disparities in achieving technical indicators such as TPT $\geq 80\%$ and TSR $\geq 90\%$ persist across provinces (Kemenkes RI, 2023). This ecological study, therefore, aims to analyze trends and correlations between TPT coverage, TSR achievement, and TB incidence (CNR) at the provincial level in Indonesia during 2021–2023, providing comprehensive insights into how these indicators contribute to TB control efforts.

METHODS

This study is an ecological study that employs a quantitative approach. It utilizes secondary data obtained from the Annual Report of the National Tuberculosis Control Program 2021–2023 (Ministry of Health of the Republic Indonesia,

2024) and accessed through the official website between April and June 2025. The population of this study includes all provinces in Indonesia, comprising 34 provinces in 2021–2022 and 38 provinces in 2023, as recorded in the national TB reporting system. The study employs a total population sampling method, meaning that all provinces with complete data on Tuberculosis Preventive Therapy (TPT) coverage, Treatment Success Rate (TSR), and TB incidence Case Notification Rate (CNR) for 2021–2023 are included.

The analysis period was selected because Indonesian TB data prior to 2021 experienced reporting instability and incomplete of TPT coverage data due to the disruption caused by the COVID-19 pandemic. WHO (2022) reported that the COVID-19 pandemic caused significant disruptions to TB services and reduced case notifications globally, rendering the 2019–2020 data unstable for epidemiological trend analysis. A study emphasized the importance of geographic consistency in spatial TB data analysis (N and I, 2021). The Indonesian Ministry of Health (2022; 2024) documented that improvements to the TPT and TSR reporting systems in Indonesia were standardized only in 2021. Furthermore, changes in Indonesia's administrative structure, with the increase from 34 to 38 in 2023, resulted in inconsistent units of analysis when using data spanning more than three years.

Provinces with incomplete data over the three-year period were excluded from the analysis. The research was conducted using publicly available secondary data and was analyzed between April and June 2025. The independent variables in this study are TPT coverage and TSR, while the dependent variable is TB incidence, represented by the Case Notification Rate (CNR), which is defined as the number of reported TB cases per 100,000 population at the provincial level. Data were collected through document review of official reports, compiled into spreadsheets, and prepared for statistical and spatial analysis.

The data analysis employed a quantitative ecological analytical design consisting of descriptive, spatial, and inferential analyses. Descriptive analysis was performed to illustrate the annual distribution and trends of TPT coverage, TSR, and CNR across provinces from 2021 to 2023, and the results were presented in tables and line charts. Spatial analysis was conducted using QGIS software to map the geographic distribution of TPT, TSR, and CNR, visualize regional disparities, and support trend interpretation.

The inferential analysis aimed to identify correlations between the independent variables (TPT and TSR) and the dependent variable (CNR). Normality tests were performed using the Shapiro–Wilk test because the number of samples per year was less than 50. Correlation analysis was conducted

separately for each year (2021, 2022, and 2023) using either Pearson or Spearman correlation tests, depending on data distribution. Correlation coefficients (ρ) were interpreted based on their strengths: very weak (<0.200), weak ($0.200-0.399$), moderate ($0.400-0.599$), strong ($0.600-0.799$), and very strong ($0.800-1.000$). These interpretations helped determine the direction and strength of the relationships among the variables.

RESULTS AND DISCUSSION

Spatial visualization is a method for displaying data in map form. This method is used to more comprehensively display variations in the trends of CNR, TPT, and TSR across provinces in Indonesia from 2021 to 2023. Epidemiological mapping is important because different geographic distributions, demographic conditions, and access to services in each region can influence TB transmission patterns and control program outcomes (Mhimbira *et al.*, 2017). Spatial analysis also allows for the identification of clusters of areas with high and low caseloads, as well as the detection of potential service gaps that are not visible through numerical analysis alone (Villalva-Serra *et al.*, 2025). Thus, this mapping provides a strong scientific basis for determining TB program intervention priorities in provinces or regions that require greater attention.

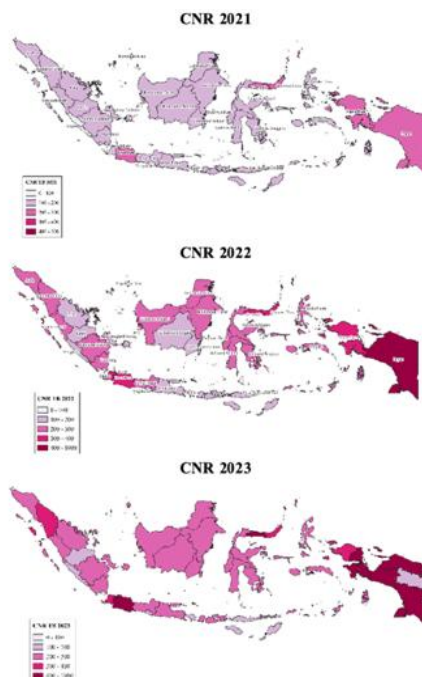


Figure 1. Case Notification Rate (CNR) in Province of Indonesia During 2021-2023

Figure 1 shows the Case Notification Rate (CNR) in the provinces of Indonesia during 2021-2023. Darker shading indicates that the Case Notification Rate (CNR) of tuberculosis in a

province is higher than in provinces with lighter shading. The CNR map indicates an increasing number of cases each year, marked by the growing number of provinces/regions appearing in darker shades. Jakarta and Papua are consistently appear darker, indicating a high CNR of tuberculosis.

This increase not only reflects a high disease burden but may also be related to improvements in case detection and recording systems following the disruptions of the COVID-19 pandemic. Global studies have noted that post-pandemic increases in notifications are a common phenomenon as health services stabilize and surveillance systems are strengthened (Chakaya *et al.*, 2022). The map also shows significant regional variation. Provinces such as Jakarta, Papua, and several provinces in Java and Nusa Tenggara appear to have higher CNRs than other provinces. This variation may be influenced by population density, high mobility, healthcare capacity, ease of access to diagnosis, and differences in regional commitment to TB control. The literature suggests that dense urban areas and remote areas tend to have higher CNRs due to a combination of transmission risk factors and disparities in access to services (Reid *et al.*, 2019).

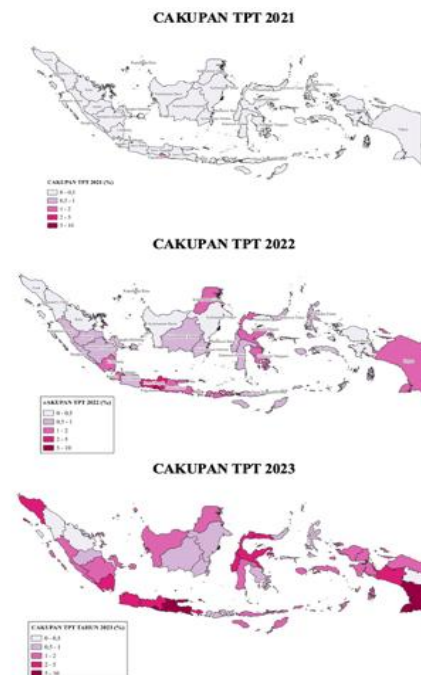


Figure 2. Tuberculosis Preventive Therapy (TPT) in Province of Indonesia during 2021-2023

Figure 2 shows the distribution of Tuberculosis Preventive Therapy (TPT) across provinces in Indonesia during 2021-2023. Most provinces/regions had low levels of Tuberculosis Preventive Therapy (TPT) (in the white to light pink category) in 2021, as TB services were being restored post-pandemic. In 2022 and 2023, most provinces/regions had moderate levels of

Tuberculosis Preventive Therapy (TPT), which fall into the pink to dark pink category. The apparent color differences reflect the disparity in TPT implementation across regions, indicating that TB prevention efforts have not been evenly distributed at the national level. Regions generally have lower TPT coverage, which may be influenced by geographic barriers, uneven distribution of health workers, and limited access to healthcare facilities.

Structural factors such as limitations in contact tracing systems, the availability of preventive drugs, and funding gaps are also frequently reported as causes of low TPT coverage in developing countries (Zenner *et al.*, 2017). This indicates the need for strategies that are more adaptive to local contexts to strengthen TPT coverage in underdeveloped areas. The increasing color intensity on the 2022–2023 maps indicates efforts to increase TPT coverage; however, nationally, it has not yet reached the recommended optimal level. Low TPT coverage directly impacts the risk of latent TB infection progressing to active disease, especially in high-risk groups. Spatial visualization is crucial because it helps identify areas requiring priority intervention and guides policies to strengthen prevention programs.

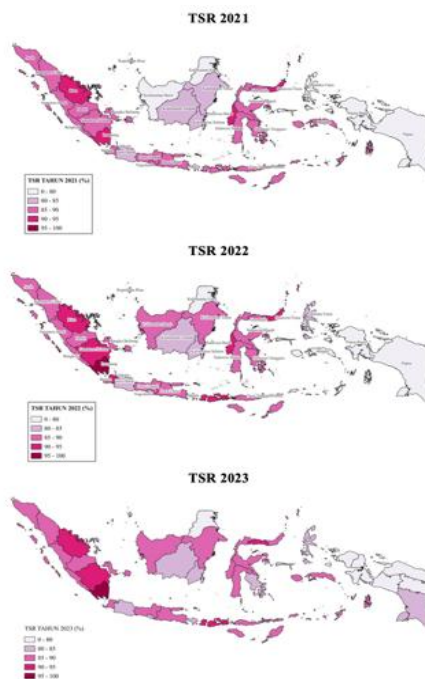


Figure 3. Treatment Success Rate (TSR) in Province of Indonesia during 2021-2023

Figure 3 shows the Treatment Success Rate (TSR) across Indonesian provinces from 2021 to 2023. Most provinces consistently show high scores (ranging from light to dark pink). However, the color variations on the map indicate uneven performance across regions, particularly when compared with nationally established success standards. These differences may reflect variations in access to

healthcare services, the availability of therapy monitoring systems, and various social determinants that influence treatment availability.

Figure 3 also reveals significant differences between western and eastern Indonesia, with provinces such as Papua, Maluku, and Nusa Tenggara still showing relatively low TSR. This disparity may arise from a combination of geographic barriers, transportation limitations, sociocultural factors, and the uneven distribution of healthcare workers. Other studies have confirmed that regions characterized by difficult access and vulnerable populations often face greater challenges in maintaining treatment success due to delayed diagnosis, lack of patient support, and logistical barriers (Gebremariam, Bjune and Frich, 2010). This situation highlights the need for a more contextualized intervention approach in these areas.

The confirmed tuberculosis (TB) cases in Indonesia showed a consistent increase from 724,309 in 2021 to 821,200 in 2023. This rise aligns with the upward trend in the case notification rate (CNR), which grew from 163 per 100,000 population in 2021 to 266 in 2022 and 293 in 2023. At the provincial level, DKI Jakarta, Papua, and Gorontalo consistently recorded the highest CNR values, while Bali and Yogyakarta recorded the lowest. In 2023, following Indonesia's expansion to 38 provinces, South Papua recorded the highest CNR (826.42), followed by Papua (698.13) and Central Papua (628.41).

Tuberculosis Preventive Treatment (TPT) coverage also increased during this period. In 2021, most provinces recorded coverage of less than 2%, but by 2023, national coverage had increased significantly. Banten had the highest TPT coverage (10.1%), followed by Yogyakarta (7.5%) and South Papua (6.3%). However, several provinces still showed low TSR values, at below 1%. This indicates systemic challenges in treatment continuity. Low TSR is often associated with patient non-adherence, delays in treatment initiation, and poor patient monitoring during the intensive and continuation phases. Open-access studies indicate that socioeconomic factors such as low health literacy, job instability, and transportation costs are the main causes of loss to follow-up, thereby lowering TSR (Gebreweld *et al.*, 2018). Despite this, many provinces still maintain high TSRs, above 80%. The highest rates were recorded in Riau, South Sumatra, Lampung, and Banten (>90%), while Papua and surrounding regions continued to record the lowest success rates, particularly in Highlands Papua (58%), West Papua (71%), and Central Papua (76%). Therefore, improving TSR requires a multidimensional approach that includes health system strengthening, community support, and improving service access.

Based on figure 1, the CNR map shows darker shades each year, indicating an increase in

case notifications, particularly in Jakarta and Papua. Meanwhile, Yogyakarta consistently has a low CNR. A low CNR is closely linked to the performance of TPT and TSR because these three indicators influence each other in the TB control cycle. A low CNR means many TB cases go undetected and are not included in the reporting system, preventing close contacts from being identified and optimally provided with TPT. Open-access studies show that TPT implementation is highly dependent on the effectiveness of contact tracing and active case finding, so areas with low case detection tend to have limited TPT coverage ((Alsdurf *et al.*, 2016)).

In summary, from 2021 to 2023, Indonesia experienced an upward trend in TB detection and reporting, increased preventive treatment coverage, and stable treatment success, with regional disparities highlighting the need for focused

interventions in the eastern provinces. The Shapiro-Wilk test was used to test for normality, as it is more sensitive and recommended for small sample sizes (fewer than 50 samples). Data can be considered normally distributed if the p-value is greater than 0.05.

The Correlation between Coverage TPT And TSR with Number Incident TBC in Indonesia 2021

This research analyzes the correlation of TPT and TSR with the number of TBC incidents using the Spearman test. The number of TB incident is represented by the Case Notification Rate (CNR). Table 4 to table 6 are the result of the correlation analysis between TPT and TSR with CNR over three years from 2021 to 2023.

Table 4. The Correlation Test of TPT and TSR with CNR in Indonesia 2021

	CNR	
	Correlation Coefficient	N
TPT	-0.236	34
TSR	-0.043	34

Based on Table 4, the Spearman rank correlation test yielded a correlation coefficient of -0.236, indicating a negative relationship between TPT coverage and the TB incidence rate (CNR). This means that higher TPT coverage tends to lower the number of TB incidents. Meanwhile, the correlation between TSR and the TB incidence rate (CNR) was -0.043, indicating a negative relationship, meaning that higher TSR tends to lower the number of TB incidents. Therefore, it can be concluded that higher TPT coverage and TSR have a negative relationship with the number of TB incidents, although this relationship is considered very weak. Although Table 4 shows a negative correlation, this result should be interpreted with caution due to several programmatic and methodological factors.

The protective effect of TPT on TB incidence typically emerges over time and depends on coverage, adherence, and the target population. Therefore, short-term increases in TPT coverage may not immediately lead to a reduction in case notifications at the provincial level (Uppal, A. *et al.*, 2021). Furthermore, variations in detection capacity and active case-finding practices across provinces,

including diagnostic availability, screening routines, and private sector involvement, significantly influence the CNR. Regions with weak detection will exhibit a low CNR despite a high actual disease burden.

The Correlation between TPT and TSR Coverage and Number Incidence TBC in Indonesia 2022

Based on the results of the Spearman rank correlation test, the correlation coefficient between TPT coverage and the number of TB cases is -0.071. This indicates a negative or inverse relationship, meaning that higher TPT coverage tends to result in lower TB cases. The correlation coefficient between the 2022 TSR and the 2022 TB Incidence Rate (CNR) is 0.174. This indicates a positive relationship, meaning that higher TSR is associated with higher reported TB cases. However, the relationship between TPT coverage and the number TB cases, and between TSR and the number of TB cases in 2022, are very weak and do not demonstrate a strong linear relationship.

Table 5. The Correlation Test of TPT and TSR with CNR in Indonesia 2022

	CNR	
	Correlation Coefficient	N
TPT	-0.071	34
TSR	-0.174	34

The notification-based incidence rate (CNR) is highly dependent on case detection capacity in each region. Weak detection practices

can lead to low incidence rates, despite a high actual disease burden, due to underreporting. As shown in a study, detection can dampen the relationship

between TB program achievement and TB incidence rates (Ereso *et al.*, 2020).

The Correlation between TPT and TSR Coverage and TB Incidence Rates in 2023

Based on the Spearman correlation test in Table 6, the correlation between Tuberculosis Preventive Therapy (TPT) coverage and the TB incidence rate (CNR) in 2023 was 0.129. The correlation between TPT coverage and the number

of TB cases in 2023 showed a positive relationship. Meanwhile, the correlation between Treatment Success Rate (TSR) and CNR had a coefficient of -0.254, indicating a negative relationship. This suggests a trend in which higher treatment success rates are associated with a decline in TB cases, although the relationship is relatively weak. The number of analysis units in 2023 was 38 provinces, adjusted for the expansion of Indonesia's administrative regions.

Table 6. The Correlation Test of TPT and TSR with CNR in Indonesia 2023

	CNR	
	Correlation Coefficient	N
TPT	0.129	38
TSR	-0.254	38

This weak correlation suggests that the dynamics of TB incidence decline are influenced not only by treatment success and TPT coverage, but also by the highly variable case detection capacity across provinces. Several studies have confirmed that provinces with limited diagnostic capacity, uneven use of detection tools, or low implementation of active screening often show apparently low incidence despite a higher actual disease burden (Htet *et al.*, 2018). Therefore, the results in Table 6 underscore that efforts to reduce TB incidence require strengthening detection capacity, expanding community screening, and mitigating the social and clinical risk factors that influence TB epidemiology in Indonesia.

The trend in tuberculosis (TB) case notification in Indonesia is an essential indicator for assessing the performance of the national TB control program. Data from 2021 to 2023 show a consistent increase in confirmed TB cases and the Case Notification Rate (CNR). In 2021, Indonesia recorded the lowest CNR of the three years, largely due to the lingering impact of the COVID-19 pandemic, which disrupted health services and reduced TB detection capacity nationwide. However, the years 2022 and 2023 marked the post-pandemic recovery phase, during which active case finding and health service delivery improved significantly. Despite this progress, the gap between estimated TB cases and those detected remains, as highlighted in the WHO Global Tuberculosis Report 2024. According to WHO, Indonesia's improved TB reporting system, modernized with digital health technologies and enhanced data management, has reduced underreporting. Underreporting refers to TB cases that occur in the community but are not officially recorded in national health systems. The government's reforms in data systems, capacity-building for health workers, and the adoption of e-health tools have enhanced the quality of case documentation and reporting, allowing previously undetected cases to be identified.

The pandemic period in 2020 severely disrupted TB services, reducing case detection. An increase in CNR does not necessarily reflect a rise in TB incidence; it may instead signify stronger surveillance and reporting. Thus, the steady increase in CNR represents progress in case detection but must be followed by improvements in preventive therapy coverage (TPT) and Treatment Success Rates (TSR) to reduce the actual burden of disease.

Provincial differences in CNR highlight disparities in health service capacity, surveillance systems, and disease burden. High CNR provinces like Jakarta, Papua, and Gorontalo may have either high TB burdens or stronger detection systems, while low CNR provinces such as Bali and Yogyakarta might reflect limited case finding rather than low incidence. Socioeconomic barriers poverty, low education, and limited financial access also restrict TB service utilization. Nurjannah and Maria (2021) further noted that low-CNR areas often have hidden or undetected TB populations.

Between 2021 and 2023, Jakarta and Papua consistently recorded the highest CNR values, indicating persistent TB transmission or strong surveillance systems. By 2023, the most notable increase occurred in South Papua, which became the province with the highest national CNR following the administrative division of Papua into several new provinces. In contrast, Bali and Yogyakarta maintained the lowest rates, underscoring regional disparities that call for localized strategies: intensive interventions in high-burden regions and surveillance maintenance in low-burden ones. In terms of Tuberculosis Preventive Treatment (TPT), Indonesia achieved significant expansion from 2021 to 2023. Yogyakarta consistently recorded the highest coverage, correlating with its low CNR, suggesting that strong preventive efforts contribute to fewer active cases. In contrast, Jakarta showed both high TPT coverage and high CNR, illustrating that high notification rates do not always indicate program failure but can reflect effective detection

systems in densely populated and well-resourced areas. Hence, the relationship between TPT coverage and CNR is complex; low CNR may indicate effective prevention, while high CNR may reflect strong surveillance.

Treatment Success Rate (TSR) varied among provinces during the same period. Lampung demonstrated consistently high TSR and low CNR, implying that successful treatment has helped interrupt transmission chains. When TB patients complete treatment successfully, they no longer spread the infection, leading to fewer new cases over time. Conversely, Papua displayed the opposite trend low TSR and high CNR revealing significant challenges in treatment adherence and patient outcomes. Many patients there failed to complete treatment, increasing the risk of ongoing transmission. Despite good case detection, poor treatment success means that TB remains prevalent, posing a substantial burden on the regional health system.

Statistical analysis of provincial data from 2021–2023 shows a weak and statistically insignificant correlation between TPT coverage and CNR. Although the relationship was negative in 2021–2022 (indicating that higher TPT coverage tends to reduce TB incidence), it became slightly positive in 2023. This shift may be explained by: (1) simultaneous strengthening of case detection systems, leading to more reported cases; (2) discrepancies between reported and actual effective TPT implementation; and (3) a time-lag effect, as the preventive impact of TPT may take several years to materialize. Therefore, short-term correlations may not capture long-term program outcomes.

Similarly, the correlation between TSR and CNR from 2021–2023 was weak and statistically insignificant. A high CNR often reflects effective case detection, whereas TSR captures treatment performance. Their interaction depends on broader systemic and contextual factors, including healthcare access, patient behavior, and external crises such as the COVID-19 pandemic. Globally, evidence supports that improving case detection (CNR) often leads to higher TSR through early diagnosis and treatment initiation. For instance, Liberia, Afghanistan, and Somalia reported TSR values between 81 and 90% despite limited public health access (Desta *et al.*, 2018). In India, collaboration between public and private sectors boosted both CNR and TSR, demonstrating the effectiveness of integrated interventions (Utomo *et al.*, 2022). The European experience during the COVID-19 pandemic contrasts sharply: CNR declined in 2020–2021 due to service disruptions, which subsequently reduced TSR as fewer patients were diagnosed and treated (Cristea *et al.*, 2023). Moreover, in conflict zones such as Sudan, limited healthcare access led to low CNR and poor TSR outcomes (Gebreyohannes

et al., 2024), emphasizing the role of sociopolitical context in TB dynamics.

Overall, the Indonesian TB program between 2021 and 2023 demonstrated progress in case detection and data reporting; however, persistent gaps remain in preventive therapy coverage and treatment outcomes. While rising CNR figures may initially suggest a growing disease burden, they also indicate improvements in surveillance systems. Sustainable progress will depend on integrating preventive strategies, strengthening treatment adherence, and addressing regional inequities to achieve long-term TB elimination goals.

This research has the advantage of providing a comprehensive national overview of trends and relationships among Tuberculosis Preventive Therapy (TPT) coverage, Treatment Success Rate (TSR), and Case Notification Rate (CNR) across all Indonesian provinces during the 2021–2023 period. The use of official data from the Indonesian Ministry of Health enhances the validity and reliability of the study's results. Furthermore, the results demonstrate inequalities in the tuberculosis control program across Indonesia over the three-year period. However, this study has several limitations. As an ecological study, it cannot explain direct causal relationships or describe individual-level variations, such as treatment adherence, socioeconomic factors, or access to health services. Furthermore, the use of secondary data depends on the completeness and consistency of reporting across provinces, potentially introducing data bias.

CONCLUSION

This study shows variations in the trends and distribution of Tuberculosis Preventive Therapy (TPT) coverage, Treatment Success Rate (TSR), and Case Notification Rate (CNR) across provinces in Indonesia during 2021–2023. Several provinces showed improvements in TPT and TSR, although regional disparities remain evident and could potentially impact efforts to achieve the national TB elimination target. These findings confirm that the strength of a TB program depends not only on service coverage but also on the consistency of provincial performance in maintaining successful therapy and active case detection. The scope of this study maintained a focused ecological analysis due to considerations of data consistency and the risk of spatial bias. Provincial-level TB indicator data only reached stable reporting standards in 2021, so extending the analysis period or adding additional ecological variables could potentially introduce ecological bias. Furthermore, changes in the provincial administrative structure in 2023 could potentially disrupt comparability between regions. Incorporating additional variables without data

equivalence could also create neighborhood effect averaging problems, which could obscure true epidemiological patterns (Kwan, 2018). Therefore, the analysis focused on the 2021–2023 period to maintain the validity and integrity of the study methodology. Further research could be pursued with a longitudinal or individual-based approach to examine the influence of the TPT lag time on the decline in active TB cases. The study could also be expanded to include other contextual factors such as socioeconomic status, population density, and access to health services.

Acknowledgement

Special thanks to the Indonesian Ministry of Health, which informed us of tuberculosis cases in Indonesia from 2021-2023. We also acknowledge the contribution of our academic advisors for their valuable feedback and guidance during the development of this manuscript.

Conflict of Interest and Funding Disclosure

None.

Author Contributions

NB: Researcher, writing article, editing, conceptualization, data collection, analysis and interpretation of result; CUW: Supervision; KDA: Supervision.

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