



Geographic and Temporal Patterns of Tuberculosis Treatment Initiation in Lampung Province, Indonesia: An Analysis of Routine Surveillance Data

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Abstract: -

Background: Tuberculosis (TB) treatment initiation is a critical transition in the care cascade, yet subnational geographic and temporal patterns may be obscured by aggregated estimates. This study characterized patterns of documented TB treatment initiation in Lampung Province, Indonesia.

Methods: We conducted a retrospective observational study using routine TB surveillance data from January to December 2025. All patients residing in Lampung Province with documented treatment initiation were included. Demographic characteristics and monthly and district/city distributions were described. Geographic and temporal variation in treatment initiation counts across 15 districts/cities was assessed using negative binomial regression, with adjusted count ratios (CRs) and 95% confidence intervals (CIs).

Results: Among 20,314 patients, the median age was 46 years (IQR 26–60), 60.5% were male, and 33.7% were aged 45–64 years. Treatment initiations varied substantially geographically, with the highest proportion recorded in Bandar Lampung (15.9%), followed by Lampung Selatan (13.5%) and Lampung Tengah (11.6%). Geographic variation remained significant after adjustment for calendar month ($p < 0.001$). Compared with Bandar Lampung, adjusted treatment initiation counts were lowest in Pesisir Barat (CR 0.11; 95% CI 0.09–0.13), Metro (0.12; 0.10–0.14), and Mesuji (0.13; 0.11–0.16). Temporal variation was also significant ($p < 0.001$), with December showing the largest reduction relative to January (CR 0.68; 95% CI 0.58–0.78).

Conclusions: TB treatment initiation in Lampung showed marked geographic and temporal heterogeneity. These findings represent variation in recorded treatment volumes rather than treatment coverage. Linking surveillance records with diagnostic denominators, population data, and multi-year observations could strengthen subnational monitoring and guide locally targeted TB control strategies.

Keywords: tuberculosis; treatment initiation; surveillance; geographic variation; temporal patterns; Indonesia.

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Introduction

Tuberculosis (TB) remains a major global public health challenge despite being preventable and curable with effective treatment. In 2024, an estimated 10.7 million people developed TB worldwide and approximately 1.23 million died from the disease, making TB the leading cause of death from a single infectious agent (1). The burden remains highly concentrated geographically, with 30 high-TB-burden countries accounting for 87% of global incident cases and only eight countries contributing approximately two-thirds of the total burden (1). Although global TB incidence declined slightly between 2023 and 2024, the reduction since 2015 remains substantially below the milestones established by the World Health Organization (WHO) End TB Strategy (1,2). These persistent gaps highlight the importance of ensuring that people with TB are not only diagnosed but also promptly linked to and initiated on effective treatment.

Treatment initiation represents a critical transition in the TB care cascade, connecting case detection with effective clinical management and interruption of transmission. Globally, 8.3 million people were newly diagnosed with TB and accessed treatment in 2024, representing approximately 78% of the estimated number of people who developed the disease (1). Delays or losses between diagnosis and treatment initiation may prolong infectiousness, increase the risk of clinical deterioration and mortality, and sustain community transmission (3,4). Evidence from high-burden settings indicates that delays in TB diagnosis and treatment are influenced by multiple patient-, socioeconomic-, geographic-, and health-system factors, including rural residence, financial insecurity, referral pathways, limited access to health services, and administrative barriers (3). Accordingly, the WHO End TB Strategy emphasizes early diagnosis, treatment of all people with TB, patient-centred care, and universal access to high-quality TB services as essential components of TB elimination (2,5).

Indonesia is central to the global TB response because it accounts for approximately 10% of the world's incident TB cases, the second-largest national contribution after India (1). The large absolute burden, combined with the country's extensive and geographically diverse health system, creates substantial challenges for ensuring continuity between diagnosis and treatment. Previous Indonesian evidence has demonstrated losses and delays along the TB care cascade. Among patients diagnosed with rifampicin-resistant TB in West Java, for example, 85% initiated second-line treatment, while losses occurred between diagnosis and pre-treatment assessment, and rural residence was associated with delayed treatment initiation (6). More recent evidence from Indonesian primary-care pathways similarly showed that not all patients diagnosed with TB had documented treatment initiation and identified differences in delays

according to patient and referral characteristics (7). At the national level, analyses of routine surveillance data have also demonstrated substantial regional and population-level heterogeneity in TB treatment outcomes, suggesting that national averages may conceal important subnational differences in programme performance (8).

Geographic variation is particularly relevant in Indonesia, where differences in population distribution, health-care infrastructure, referral networks, urbanization, and accessibility may shape how TB services are delivered across provinces and districts. The WHO emphasizes that geographical and financial barriers can limit access to TB services and that progress towards universal health coverage requires equitable access to diagnosis and treatment, particularly among vulnerable and underserved populations (5,9). Examining TB indicators at subnational level is therefore important because aggregated national estimates may obscure local variation and temporal fluctuations that are operationally relevant for programme planning. Routine surveillance systems provide an opportunity to identify such patterns using large-scale programmatic data collected across health facilities and administrative areas.

Lampung Province provides an important setting for examining these subnational patterns. Located at the southern end of Sumatra and comprising both urban and predominantly non-metropolitan districts, the province encompasses heterogeneous geographic and health-service contexts. However, evidence describing how TB treatment initiation is distributed across districts and over time in Lampung remains limited. Most available TB research in Indonesia has focused on national treatment outcomes, diagnostic delays, drug-resistant TB, or individual-level determinants, while less attention has been given to the geographic and temporal distribution of patients entering treatment at the provincial and district levels (6–8). Understanding these patterns can identify areas with disproportionately high or low treatment volumes, reveal temporal fluctuations in treatment initiation, and provide a programmatic basis for more targeted allocation of TB services and resources.

Routine TB surveillance data are particularly valuable for this purpose because they reflect real-world service delivery across large populations and can reveal patterns that may not be captured in smaller facility-based studies. Nevertheless, surveillance-based analyses must distinguish between the number and distribution of patients initiating treatment and population-level treatment coverage, which requires an appropriate denominator of all diagnosed or estimated TB cases. In this context, examining treatment initiation as a geographic and temporal programme pattern can provide evidence on where and when patients enter TB treatment services without assuming that the observed numbers represent treatment coverage. Therefore, this study

aimed to characterize the geographic and temporal patterns of TB treatment initiation across districts and cities in Lampung Province, Indonesia, using routine TB surveillance data from 2025. The study also examined the distribution of treatment initiation according to patient, disease, and health-service characteristics to identify programmatically relevant variations that may inform subnational TB control strategies.

Methods

Study design and setting

We conducted a retrospective observational study using routinely collected tuberculosis (TB) surveillance data from Lampung Province, Indonesia, covering the period from 1 January to 31 December 2025. The study was designed to characterize the geographic and temporal patterns of TB treatment initiation and to describe variations according to patient, disease, and health-service characteristics. The reporting of this study was guided by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations for observational studies (21).

Lampung Province is located at the southern end of Sumatra, Indonesia, and administratively comprises 15 districts and cities: Bandar Lampung City, Metro City, Lampung Barat, Lampung Selatan, Lampung Tengah, Lampung Timur, Lampung Utara, Mesuji, Pesawaran, Pesisir Barat, Pringsewu, Tanggamus, Tulang Bawang, Tulang Bawang Barat, and Way Kanan. The province contains both urban and predominantly non-metropolitan populations served by a heterogeneous network of primary health-care facilities, hospitals, and other health-care providers involved in TB diagnosis, notification, and treatment.

Data source

Data were obtained from Indonesia's routine TB surveillance system (Sistem Informasi Tuberkulosis/SITB). The surveillance dataset contained individual-level records of patients registered for drug-susceptible TB treatment during 2025. The dataset used for this analysis included information on month of treatment initiation, province and district/city of patient residence, province and district/city of the reporting health facility, health-facility name, age, sex, occupation, pregnancy status, TB diagnostic classification, anatomical site of disease, previous treatment history, HIV status, paediatric TB score, treatment initiation date, anti-TB treatment regimen, microbiological examination, HIV testing, antiretroviral therapy, diabetes-related information, treatment completion date, and final treatment outcome.

Study population

The source population comprised patients with TB recorded in the routine surveillance system during 2025. For the

present analysis, the study population was restricted to patients with a recorded province of residence of Lampung. Records were eligible for inclusion if they: (1) were recorded as residing in Lampung Province; (2) had a documented TB treatment initiation date between 1 January and 31 December 2025; and (3) were included in the drug-susceptible TB surveillance dataset used for the analysis. No age or sex restrictions were applied.

Records outside Lampung Province were excluded. For analyses requiring district/city of residence, observations with missing or blank district/city information were excluded only from the relevant district-level analyses rather than from the overall provincial analysis.

Study size

No formal sample-size calculation was performed because the study used all eligible records available in the routine surveillance dataset for Lampung Province during the predefined study period. Therefore, the analytical sample represented a census of eligible records in the available surveillance dataset rather than a probability-based sample. The final provincial analytical dataset consisted of 20,314 treatment initiation records. District-level analyses included 20,313 records with non-missing district/city-of-residence.

Outcome and operational definition

The primary measure of interest was TB treatment initiation, operationalized as the presence of a recorded treatment initiation date during the study period. All records in the Lampung analytical dataset had a documented treatment initiation date. Consequently, the study did not estimate *treatment initiation coverage* or the probability of initiating treatment among all diagnosed patients. Instead, it examined the volume, distribution, and temporal pattern of documented treatment initiations among patients recorded as having started treatment.

Treatment initiation date was originally recorded in day/month/year format and converted into a standardized date variable for analysis. Calendar month was derived from the treatment initiation date and categorized into the 12 months from January through December 2025.

The monthly number of treatment initiations was defined as the number of patient records with a treatment initiation date occurring within each calendar month. Geographic treatment initiation volume was defined as the number of treatment initiations recorded among residents of each district or city during 2025.

Importantly, the number of treatment initiations was interpreted as the count of patients entering treatment in the surveillance dataset, rather than as a treatment initiation rate or coverage indicator. Estimating treatment initiation coverage would require a denominator that includes all patients diagnosed or otherwise eligible for treatment,

including those who did not initiate treatment; such a denominator was not available in the analytical dataset.

Geographic variables

The primary geographic variable was the patient's district or city of residence. Geographic analyses were therefore based on patient residence rather than the location of the reporting or treating health facility. This approach was selected to characterize the geographic distribution of patients receiving TB treatment within Lampung Province.

The dataset also contained health-facility location variables, including the health facility's province district/city. These variables were retained for descriptive and supplementary analyses, but were not used to define the patient's geographic residence. District/city names were standardized prior to analysis to remove formatting differences while preserving the 15 administrative units of Lampung Province.

Patient and clinical variables

Patient-level demographic characteristics available for analysis included age, sex, occupation, and pregnancy status. Age was analyzed initially as a continuous variable and summarized using appropriate measures of central tendency and dispersion. For categorical analyses, age was grouped into epidemiologically meaningful categories (0–14, 15–24, 25–44, 45–64, and ≥ 65 years).

Sex was analyzed according to the categories recorded in the surveillance system. Occupation was retained according to the available surveillance categories and, where necessary, categories with small frequencies were combined into broader groups for descriptive analysis.

Temporal variables

The treatment initiation date was converted from character format to a valid calendar-date variable using day-month-year parsing. The month of treatment initiation was subsequently derived directly from this date. Internal consistency between the existing bulan variable and the month derived from the treatment initiation date was assessed. The two variables showed complete agreement in the Lampung dataset, supporting the interpretation of bulan as the calendar month of treatment initiation. Monthly treatment initiation counts were calculated for January through December 2025. Temporal patterns were examined at both provincial and district/city levels to identify fluctuations in the volume of patients initiating treatment throughout the year.

Data management and quality control

Data cleaning and management were performed before statistical analysis. Variable names were standardized to lower-case machine-readable format. Character variables used for geographic filtering were trimmed for leading and trailing spaces and standardized for capitalization.

Treatment initiation dates were parsed from character strings in day/month/year format. Records were checked for missing treatment initiation dates, invalid date formats, and dates outside the predefined study period. All 20,314 Lampung records had a non-missing treatment initiation date.

Geographic completeness was assessed using the district/city of patient residence. One record had a blank district/city value. This observation was retained in the overall provincial analysis but excluded from district/city-specific analyses, resulting in 20,313 observations for geographic comparisons. The month variable in the source dataset was cross-tabulated with the month derived independently from the treatment initiation date. Complete concordance was observed across all 12 months, providing an internal consistency check for the temporal variable.

Missing data

Missingness was assessed separately for each variable included in the analysis. No imputation was planned because the study primarily aimed to describe routinely collected surveillance data and because imputation could introduce assumptions that were not supported by the underlying programme data.

For descriptive analyses, the denominator for each variable was based on the number of observations with available data, and missing values were reported where relevant. For district-level analyses, the single observation without district/city information was excluded from geographic comparisons but retained in the overall provincial estimates.

For subsequent multivariable analyses, if performed, a complete-case approach will be used unless the extent and pattern of missingness indicate that multiple imputation is warranted. The proportion of missing observations for each candidate predictor will be assessed before model construction.

Statistical analysis

All analyses were conducted using R statistical software (R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics were used to summarize demographic, clinical, geographic, and health-service characteristics of patients initiating TB treatment. Categorical variables were summarized as frequencies and percentages. Continuous variables were examined for distributional characteristics and summarized using the mean and standard deviation for approximately normally distributed data, or the median and interquartile range (IQR) for skewed distributions.

The total number of treatment initiations was calculated for Lampung Province and separately for each of the 15 districts/cities. District/city contributions to the provincial treatment initiation volume were expressed as:

$$\text{District contribution (\%)} = \frac{\text{Number of treatment initiations in district } i}{\text{Total treatment initiations in Lampung}} \times 100.$$

Because no population or diagnosed-case denominator was incorporated into the present dataset, these percentages represent each district's share of all recorded treatment initiations and were not interpreted as incidence rates or treatment coverage.

Temporal analysis

Monthly treatment initiation counts were calculated for each calendar month from January to December 2025. Temporal variation was visualized using line plots showing monthly counts at the provincial level.

The absolute and relative month-to-month changes in treatment initiation were calculated as:

$$\Delta N_t = N_t - N_{t-1}$$

and

$$\% \Delta_t = \frac{N_t - N_{t-1}}{N_{t-1}} \times 100,$$

where N_t represents the number of treatment initiations in month t .

Because only 12 monthly observations were available for a single calendar year, the primary temporal analysis was descriptive. Formal long-term time-series modelling, including autoregressive integrated moving average models or seasonal decomposition, was not undertaken because the available time series was insufficient to reliably characterize long-term trends or seasonality.

Geographic analysis

Geographic variation was assessed by comparing the number and proportional distribution of treatment initiations across the 15 districts and cities. Districts/cities were ranked according to annual treatment initiation volume.

Monthly counts were additionally cross-classified by district/city to examine within-province geographic and temporal heterogeneity. These data were presented using a district-by-month heatmap and small-multiple temporal plots where appropriate.

Because the analysis did not incorporate district-level population denominators or estimated TB burden, differences in absolute treatment initiation counts were not interpreted as direct measures of district-level TB incidence, programme performance, or access to treatment. Higher counts may reflect differences in population size, underlying TB burden, case detection, health-service utilization, referral patterns, or reporting completeness.

Analysis of patient and clinical characteristics

Treatment initiations were stratified according to demographic and clinical characteristics, including age group, sex, diagnostic classification, disease site, previous treatment history, HIV status, and other variables with adequate data completeness.

Differences in categorical characteristics across districts/cities were evaluated using Pearson's chi-square test, or Fisher's exact test when expected cell frequencies were insufficient for the chi-square approximation. For continuous variables, between-group differences were evaluated using analysis of variance for approximately normally distributed variables or the Kruskal–Wallis test for non-normally distributed variables.

Effect sizes and 95% confidence intervals were reported where applicable rather than relying solely on statistical significance. All statistical tests were two-sided, and a P -value <0.05 was considered statistically significant.

Exploratory count modelling

If inferential analysis of geographic and temporal variation is included in the final manuscript, monthly district-level treatment initiation counts may be modelled using count-regression methods. Poisson regression would initially be considered, with district/city and calendar month included as explanatory variables. The presence of overdispersion would be assessed by comparing the residual deviance with the residual degrees of freedom and by examining the variance-to-mean relationship.

If substantial overdispersion is identified, negative binomial regression would be preferred. Results would be expressed as incidence rate ratios (IRRs) with 95% confidence intervals. However, because the present data do not include a population or eligible-patient denominator, such models would describe relative treatment initiation counts rather than population-based treatment initiation rates. The term IRR would therefore need to be used cautiously, particularly if no population offset is incorporated. A negative binomial model of counts with an appropriate population offset would be considerably stronger.

Data visualization

Temporal and geographic patterns were visualized using the ggplot2 package in R. Provincial monthly trends were displayed using line plots with individual monthly observations. District/city variation was presented using ranked horizontal bar charts. Geographic–temporal variation was visualized using district-by-month heatmaps and faceted monthly trend plots.

All figures were generated using consistent axis scales, labels, and graphical formatting and exported as high-

resolution Portable Network Graphics (PNG) files suitable for publication.

Bias and sensitivity considerations

Several potential sources of bias were considered. First, the study relied on routinely collected surveillance data and was therefore subject to incomplete reporting, data-entry errors, misclassification, and differences in reporting practices between health facilities and districts. Data-quality checks were performed for the primary geographic and temporal variables to reduce the impact of obvious inconsistencies.

Second, selection into the analytical dataset was conditional on having a documented treatment initiation date. Consequently, patients diagnosed with TB who did not initiate treatment were not represented in the dataset. This creates an inherent selection mechanism and prevents estimation of treatment initiation coverage or pre-treatment loss to follow-up.

Third, comparisons of absolute treatment initiation counts between districts may be influenced by differences in population size, underlying TB burden, diagnostic activity, health-care access, and surveillance completeness. District-level counts were therefore interpreted descriptively and not as direct measures of programme performance.

Sensitivity analyses include the exclusion of observations with incomplete geographic information, the comparison of results using patient residence versus health-facility location, and the assessment of whether monthly patterns materially change after stratification by major diagnostic and demographic characteristics.

Reporting guidelines

The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement. STROBE provides a 22-item framework for transparent reporting of observational studies, including specification of study design, setting, participants, variables, data sources, bias, study size, missing data, and statistical methods.

Ethical considerations

This study involved secondary analysis of routinely collected TB surveillance data. The analytical dataset contained no direct personal identifiers and no direct contact with patients was undertaken.

Result

A total of 20,314 patients with documented tuberculosis treatment in Lampung Province in 2025 were included in the analysis. The median age was 46 years (IQR: 26–60 years). Patients aged 45–64 years constituted the largest age group (6,854; 33.7%), followed by those aged 25–44 years (5,023; 24.7%) and ≥ 65 years (3,725; 18.3%). Children aged <15

years accounted for 2,931 (14.4%) of treatment initiations, while patients aged 15–24 years accounted for 1,781 (8.8%). Overall, more than half of the patients initiating treatment were aged ≥ 45 years. Males predominated, accounting for 12,295 (60.5%) patients compared with 8,019 (39.5%) females (Table 1).

Table 1. Characteristics of tuberculosis patients initiating treatment in Lampung Province, Indonesia, 2025

Characteristics	Overall, N = 20,314 ¹
Age, years	46.0 (26.0–60.0)
Age group	
<15 years	2,931 (14.4%)
15–24 years	1,781 (8.8%)
25–44 years	5,023 (24.7%)
45–64 years	6,854 (33.7%)
≥ 65 years	3,725 (18.3%)
Sex	
Male	12,295 (60.5%)
Female	8,019 (39.5%)
District/city	
Kota Bandar Lampung	3,233 (15.9%)
Kota Metro	375 (1.8%)
Lampung Barat	537 (2.6%)
Lampung Selatan	2,733 (13.5%)
Lampung Tengah	2,360 (11.6%)
Lampung Timur	2,203 (10.8%)
Lampung Utara	1,182 (5.8%)
Mesuji	438 (2.2%)
Pesawaran	1,449 (7.1%)
Pesisir Barat	363 (1.8%)
Pringsewu	748 (3.7%)
Tanggamus	2,047 (10.1%)
Tulang Bawang Barat	623 (3.1%)
Tulangbawang	940 (4.6%)
Way Kanan	1,083 (5.3%)

¹Median (Q1–Q3); n (%)

The geographic distribution of treatment initiations was markedly heterogeneous. Kota Bandar Lampung contributed the largest number of patients initiating treatment (3,233; 15.9%), followed by Lampung Selatan (2,733; 13.5%), Lampung Tengah (2,360; 11.6%), Lampung Timur (2,203; 10.8%), and Tanggamus (2,047; 10.1%). Together,

these five districts/cities accounted for approximately 61.9% of all recorded treatment initiations in the province. In contrast, the lowest numbers were recorded in Pesisir Barat (363; 1.8%), Kota Metro (375; 1.8%), and Mesuji (438; 2.2%).

Temporal patterns of treatment initiation

Treatment initiation varied throughout 2025, with 1,882 patients initiating treatment in January, followed by 1,900 in February, 1,622 in March, 1,491 in April, 1,763 in May, 1,608 in June, 1,856 in July, 1,668 in August, 1,749 in September, 1,902 in October, 1,610 in November, and 1,263 in December. Thus, the highest monthly number of treatment initiations occurred in October ($n = 1,902$), closely followed by February ($n = 1,900$), whereas the lowest occurred in December ($n = 1,263$).

The monthly pattern was not characterized by a uniform increase or decrease across the year. Instead, treatment initiation fluctuated, with relatively high volumes early in the year, a decline during March–April, subsequent increases in May and July, another peak in October, and a pronounced reduction toward the end of the year. The December count was approximately 32.9% lower than that observed in January and 33.6% lower than the October peak. However, the magnitude and direction of these monthly fluctuations differed substantially across districts/cities (Fig. 1).

Geographic heterogeneity in monthly treatment initiation

District-specific monthly trajectories demonstrated substantial geographic heterogeneity (Fig. 1). Kota Bandar Lampung consistently recorded among the highest monthly treatment volumes, although marked fluctuations were observed, including a prominent mid-year peak and another period of high treatment initiation during September–October. Lampung Selatan similarly showed high treatment volumes, particularly early in the year, followed by a generally lower level in subsequent months.

Several districts displayed distinctly different temporal profiles. Pesawaran showed an increase in the second half of the year, peaking around October before declining in November and December. Way Kanan also showed substantial within-year fluctuation, including a mid-year peak followed by another increase toward the end of the year. Tulangbawang exhibited a generally higher treatment volume during the latter part of the year than at the beginning of 2025. Conversely, Lampung Barat, Mesuji, and Tulang Bawang Barat generally showed lower treatment volumes toward the end of the year. Pesisir Barat showed a distinct mid-year peak followed by a gradual decline. These district-specific trajectories indicate that the provincial monthly pattern masked considerable local variation in the timing and volume of treatment initiation.

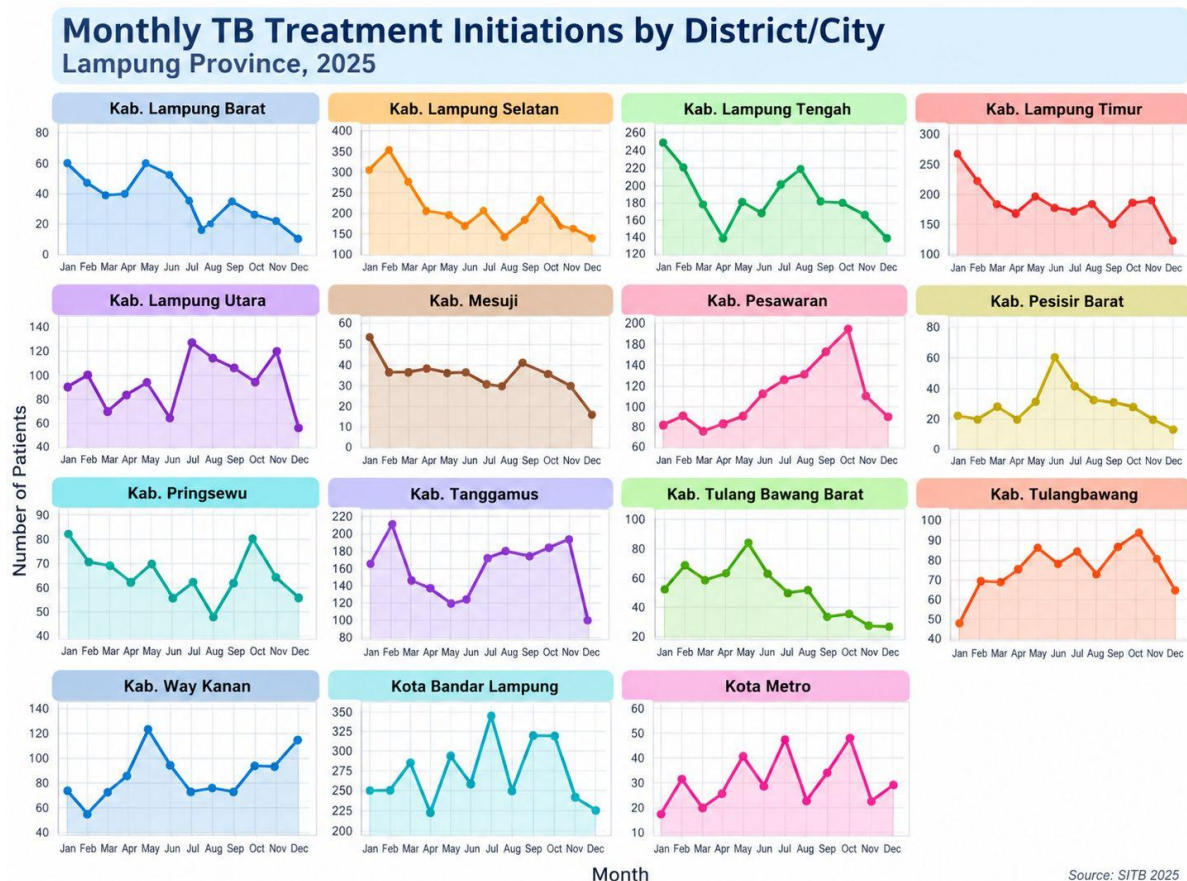


Figure 1. Monthly tuberculosis treatment initiations by district/city in Lampung Province, Indonesia, 2025.

Geographic variation in treatment initiation counts

Negative binomial regression demonstrated strong evidence of overall geographic variation in treatment initiation counts

after adjustment for calendar month (global $p < 0.001$) (Table 2). Using Kota Bandar Lampung as the reference, all other districts/cities had lower adjusted treatment initiation counts.

Table 2. Geographic and temporal variation in tuberculosis treatment initiation in Lampung Province, Indonesia, 2025

Variable	Adjusted CR	95% CI	p-value
District/city			<0.001
Kota Bandar Lampung	—	—	
Kota Metro	0.12	0.10, 0.14	
Lampung Barat	0.16	0.14, 0.19	
Lampung Selatan	0.84	0.73, 0.97	
Lampung Tengah	0.73	0.63, 0.84	
Lampung Timur	0.68	0.59, 0.78	
Lampung Utara	0.36	0.31, 0.42	
Mesuji	0.13	0.11, 0.16	
Pesawaran	0.45	0.38, 0.52	
Pesisir Barat	0.11	0.09, 0.13	
Pringsewu	0.23	0.20, 0.27	
Tanggamus	0.63	0.54, 0.73	
Tulang Bawang Barat	0.19	0.16, 0.22	
Tulangbawang	0.29	0.25, 0.34	
Way Kanan	0.34	0.29, 0.39	
Month of treatment initiation			<0.001
Jan	—	—	
Feb	0.99	0.86, 1.15	
Mar	0.87	0.75, 1.00	
Apr	0.83	0.72, 0.96	
May	1.00	0.87, 1.16	
Jun	0.92	0.80, 1.07	
Jul	1.01	0.88, 1.17	
Aug	0.89	0.77, 1.03	
Sep	0.94	0.82, 1.09	
Oct	1.02	0.89, 1.18	
Nov	0.86	0.75, 1.0	
Dec	0.68	0.58, 0.78	

The smallest adjusted count ratios (CRs) were observed in Pesisir Barat (adjusted CR 0.11; 95% CI 0.09–0.13), Kota Metro (adjusted CR 0.12; 95% CI 0.10–0.14), and Mesuji (adjusted CR 0.13; 95% CI 0.11–0.16). Thus, after accounting for calendar month, the recorded monthly treatment initiation counts in these areas were approximately 87–89% lower than those in Kota Bandar Lampung.

Lower adjusted counts were also observed in Lampung Barat (adjusted CR 0.16; 95% CI 0.14–0.19), Tulang Bawang Barat (0.19; 95% CI 0.16–0.22), Pringsewu (0.23; 95% CI 0.20–0.27), Tulangbawang (0.29; 95% CI 0.25–0.34), Way Kanan (0.34; 95% CI 0.29–0.39), and Lampung Utara (0.36; 95% CI 0.31–0.42).

Among districts with comparatively higher treatment volumes, the differences relative to Kota Bandar Lampung were less pronounced. Lampung Selatan had an adjusted CR of 0.84 (95% CI, 0.73–0.97), followed by Lampung Tengah (0.73; 95% CI, 0.63–0.84), Lampung Timur (0.68; 95% CI, 0.59–0.78), and Tanggamus (0.63; 95% CI, 0.54–0.73). Pesawaran had an adjusted CR of 0.45 (95% CI 0.38–0.52). Overall, these findings indicate pronounced differences in the volume of recorded treatment initiations across Lampung's districts and cities independent of calendar month.

Temporal variation after adjustment for district/city

There was also strong evidence of an overall calendar-month effect after adjustment for district/city (Table 2). However, the month-specific estimates indicated that this temporal variation was concentrated in selected months rather than reflecting a consistent linear decline throughout the year.

Using January as the reference, treatment initiation counts in April were approximately 17% lower (adjusted CR : 0.83; 95% CI: 0.72–0.96). The most pronounced difference occurred in December, when adjusted treatment initiation counts were approximately 32% lower than in January (adjusted CR 0.68; 95% CI 0.58–0.78).

March was borderline lower than January (adjusted CR 0.87; 95% CI 0.75–1.00), as was November (adjusted CR 0.86; 95% CI 0.75–1.00). In contrast, the confidence intervals for February (0.99; 95% CI 0.86–1.15), May (1.00; 95% CI 0.87–1.16), June (0.92; 95% CI 0.80–1.07), July (1.01; 95% CI 0.88–1.17), August (0.89; 95% CI 0.77–1.03), September (0.94; 95% CI 0.82–1.09), and October (1.02; 95% CI 0.89–1.18) included the null value. Therefore, these months did not show clear evidence of differences from January after adjustment for district/city.

Taken together, the descriptive and regression analyses demonstrate substantial geographic heterogeneity and more selective temporal variation in documented TB treatment initiation across Lampung Province during 2025.

Geographic differences were considerably larger in magnitude than most month-to-month differences, while December showed the clearest province-wide reduction in treatment initiation.

Discussion

This study provides a subnational assessment of the geographic and temporal distribution of documented TB treatment initiations in Lampung Province during 2025. Three findings are particularly important. First, the patients entering treatment were predominantly male and concentrated in middle-aged and older age groups, with 52.0% aged ≥ 45 years. Second, treatment initiation counts were highly heterogeneous across the 15 districts and cities, with Kota Bandar Lampung contributing the largest volume and substantially lower adjusted counts observed in several smaller districts. Third, treatment initiation varied across calendar months, although the temporal differences were considerably smaller than the geographic differences; December showed the clearest reduction relative to January. These findings reinforce the importance of examining routine TB surveillance data at sub-provincial levels, as aggregated estimates can conceal substantial geographic and temporal heterogeneity. Similar subnational heterogeneity has been demonstrated in nationwide Indonesian analyses of TB incidence, mortality, treatment outcomes, and healthcare utilization (9-11).

The demographic profile observed in Lampung is broadly consistent with the epidemiology of TB in Indonesia and other high-burden settings. Approximately 61% of treatment initiations occurred among men, while the largest age group was 45–64 years. Indonesian population-based evidence has shown higher pulmonary TB prevalence among middle-aged and older adults, with men having greater odds of pulmonary TB than women in these age groups (12). The contribution of older adults is also increasingly important globally. Recent analyses of WHO data estimated that adults aged ≥ 65 years accounted for 21% of global TB cases in 2023, with particularly high relative burdens in South-East Asia and a substantially greater incidence among men (13). The predominance of men may reflect a combination of biological susceptibility, smoking and occupational exposures, social contact patterns, and differences in health-seeking behaviour. However, the present study cannot determine which mechanisms underlie the observed sex distribution because it describes patients who have already initiated treatment rather than the population at risk.

The pronounced geographic heterogeneity is arguably the most important finding of this study. Kota Bandar Lampung accounted for 15.9% of all treatment initiations and remained the reference district with the highest adjusted treatment volume, whereas Pesisir Barat, Kota Metro, and Mesuji had adjusted count ratios of only 0.11–0.13. This

pattern should **not** be interpreted as evidence that these districts performed poorly in initiating treatment. The regression model analyzed absolute treatment initiation counts without a population, diagnosed case, or treatment-eligible denominator. Consequently, differences may reflect district population size, underlying TB burden, intensity of case-finding, diagnostic capacity, health service availability, referral patterns, patient mobility, private-sector engagement, or completeness of surveillance reporting. Evidence from Indonesia has previously shown substantial district-level inequalities in healthcare utilization, with urban areas generally having higher utilization than rural districts and geographical characteristics such as service availability and infrastructure contributing to these differences (14-20).

This interpretation is particularly relevant to Bandar Lampung as the provincial capital and a major concentration of health services. Indonesian patient-pathway research has demonstrated that the location at which patients initially seek care does not always align with the availability of TB diagnostic services. A national patient-pathway analysis found that only about one-fifth of patients encountered TB diagnostic capacity at their first point of care, with substantial involvement of the private sector and important subnational differences in service configuration (15). In Bandung, Lestari et al. similarly found complex pathways across public and private providers, with patients making a median of six healthcare visits before diagnosis and experiencing substantial delays before treatment initiation (16). Thus, the high number of treatment initiations recorded among residents of some Lampung districts may reflect not only differences in TB incidence but also in access to diagnosis, referral efficiency, and the capacity of local health systems to identify and enroll patients in treatment.

The temporal findings require equally cautious interpretation. Monthly treatment initiation counts fluctuated throughout 2025, with peaks in February and October and the lowest count in December. After adjustment for district/city, the overall month effect remained statistically significant, but most individual months did not differ clearly from January. April had an adjusted count 17% lower, while December showed the largest reduction, at approximately 32% below January. This suggests that the statistical evidence is more consistent with selected monthly fluctuations than with a monotonic annual decline. Furthermore, a single calendar year is insufficient to establish genuine seasonality. Demonstrating a seasonal TB pattern generally requires multiple years of monthly observations and formal time-series decomposition. Long-term studies from China and Xinjiang, for example, identified recurrent seasonal peaks only after analysing eight to ten years of monthly notification data (18-20).

The December reduction therefore deserves attention but should not automatically be attributed to biological seasonality. TB notification and treatment initiation are downstream products of several processes, including symptom recognition, healthcare seeking, diagnostic testing, referral, reporting, and treatment enrollment. Seasonal changes in any of these processes can alter recorded treatment counts. Studies from other high-burden settings have demonstrated substantial seasonal variation in TB notifications, but the timing of peaks and troughs differs geographically; for example, Pakistan showed higher notifications in the second quarter and lower notifications in the fourth quarter (21). More broadly, longitudinal analysis across countries in Africa and South-East Asia has shown that TB notification levels are influenced by health-system and socioeconomic factors as well as underlying epidemiology (22). For Lampung, therefore, the December decline could reflect service utilization, diagnostic activity, reporting practices, administrative closure at year-end, or genuine epidemiological variation. Multi-year surveillance data would be required to distinguish these possibilities.

The heterogeneity of district-specific monthly trajectories further supports a health-system interpretation rather than a single province-wide seasonal mechanism. Pesawaran showed a marked increase toward October, Way Kanan had prominent mid-year and late-year increases, while several districts showed declining volumes toward December. A recent nationwide space-time analysis across 514 Indonesian districts similarly demonstrated substantial spatial and temporal heterogeneity in TB incidence and mortality and emphasized that TB patterns cannot be adequately understood from national aggregates alone (23). The district-specific trajectories observed in Lampung could therefore be useful as a surveillance signal. Districts with abrupt or persistent deviations from their usual treatment volume could be flagged for programmatic review of case-finding, diagnostic availability, referral pathways, data completeness, and treatment enrollment, rather than being immediately classified as high- or low-performing areas.

Timely transition from diagnosis to treatment remains important because interruptions along the TB care cascade can prolong infectiousness and worsen clinical outcomes. A systematic review and meta-analysis of high-burden countries found substantial heterogeneity in diagnosis and treatment delays and identified rural residence, financial insecurity, complex care-seeking pathways, limited healthcare access, and organizational barriers as important determinants (23). Indonesian evidence is consistent with these findings. In Bandung, longer treatment delays occurred among patients with multiple pre-diagnostic healthcare visits or diagnosed by private practitioners (8), while an Indonesian study of rifampicin-resistant TB found that only 85% of diagnosed patients initiated second-line treatment and that rural residence was associated with

delayed initiation (14). More recent primary-care evidence from Indonesia documented treatment initiation among 89.8% of diagnosed TB patients and identified older age, extrapulmonary disease, and referral from another facility as factors associated with earlier delays in the diagnostic pathway (15). These findings suggest that geographic differences in Lampung warrant further investigation using data that capture the entire cascade from presumptive TB through diagnosis to treatment initiation.

The study has several implications for TB programme management. Routine surveillance should be used not merely for annual reporting but as a tool for identifying geographic and temporal anomalies. District-level dashboards could compare current monthly treatment initiations with historical district-specific baselines and trigger review when sustained deviations occur. However, absolute treatment volumes alone are insufficient for ranking district performance. Future surveillance analyses should link treatment initiation records to the number of people diagnosed with TB to calculate treatment initiation coverage and pre-treatment loss to follow-up. Incorporating district population denominators would additionally permit calculation of population-based rates, while linking facility and patient residence could identify cross-district referral flows. This is particularly important in Indonesia, where patient pathways span public and private providers and where national evidence continues to show regional heterogeneity in TB outcomes (12,17).

This study has several strengths. It included more than 20,000 treatment initiations across all 15 districts/cities in Lampung Province and covered a complete calendar year, allowing simultaneous assessment of geographic and monthly patterns. The use of routinely collected surveillance data increases programmatic relevance, while district-month count modelling allowed geographic and temporal effects to be examined jointly. The analysis also used patients' residence rather than the treating facility's location, providing a population-oriented geographic description of where treated patients lived. Routine surveillance data have proven valuable for identifying regional disparities in Indonesian TB outcomes at much larger scale (2), supporting their use for subnational programme intelligence.

Several limitations must nevertheless be emphasized. First, the analytical dataset contained only patients with a documented treatment initiation date. It therefore cannot identify patients diagnosed with TB who failed to initiate treatment, nor estimate treatment initiation coverage, the probability of treatment initiation, or pre-treatment loss to follow-up. Second, district comparisons were based on absolute counts without population or diagnosed-case denominators; adjusted count ratios consequently describe relative treatment volumes rather than differences in risk,

incidence, access, or programme performance. Third, surveillance data are susceptible to incomplete reporting, coding errors, duplicate records, and differences in reporting completeness across facilities. Fourth, only one year of data was analysed, preventing formal inference about seasonality or long-term trends. Finally, the present analysis did not incorporate district-level determinants such as population density, poverty, healthcare workforce, diagnostic capacity, urbanization, or private-sector participation, which may explain part of the observed geographic heterogeneity. These limitations are important because global and national evidence indicates that treatment access and delays arise from interacting patient, socioeconomic, geographic, and health-system factors rather than geography alone (7,8,13).

Conclusion

This study identified substantial geographic heterogeneity and significant temporal variation in documented tuberculosis treatment initiations across Lampung Province, Indonesia, during 2025. Treatment initiations were concentrated among males and adults aged 45–64 years, while the volume of patients entering treatment differed markedly across the 15 districts and cities. Bandar Lampung recorded the highest treatment volume, whereas several districts and cities had substantially lower adjusted counts. Temporal variation was less pronounced than geographic variation, although December showed the clearest reduction in treatment initiation compared with January.

These findings should be interpreted as differences in recorded treatment initiation volumes rather than treatment initiation coverage or programme performance, because the surveillance dataset included only patients with documented treatment initiation and lacked a denominator of all diagnosed or treatment-eligible TB cases. Nevertheless, the observed geographic and temporal heterogeneity demonstrates the value of routine surveillance data in identifying subnational patterns warranting further programmatic investigation. Integrating treatment records with diagnostic denominators, district population data, health-service capacity indicators, and multi-year surveillance data would enable more robust assessment of treatment initiation coverage, pre-treatment loss to follow-up, geographic inequalities, and persistent temporal patterns. Such analyses could support more targeted and locally responsive TB control strategies in Lampung Province.

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