

ARTICLE INFORMATION

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Exploratory data analysis of measles transmission among children aged 0-4 years

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Abstract

Background: Measles is a highly contagious disease that primarily affects children, particularly those aged 1–4 years, who account for the highest proportion of cases both nationally and in Jambi Province. The decline in routine immunization coverage during and after the COVID-19 pandemic has widened the immunity gap, triggering a surge in measles cases across Indonesia, including Jambi Province, where the incidence rate of suspected measles rose sharply from 0.55 per 100,000 population in 2021 to 25.05 per 100,000 in 2023, leading to outbreaks in 2022 and 2023. However, epidemiological research using individual-level surveillance data remains limited in Jambi Province.

Purpose: To analyze Exploratory Data on Measles Transmission in Children Aged 0-4 Years.

Method: This analytical descriptive research applied the *Exploratory Data Analysis* (EDA) approach using RStudio software. Secondary data is sourced from the Jambi Provincial Health Office's Measles-Rubella Case Tracking Individual Report Form (MR02). From an initial population of 456 suspected children aged 0-4 years, final samples were obtained from 332 cases that met the inclusion criteria (96 confirmed positive/equivocal cases of measles IgM and 236 negative cases). Analysis and visualization of the place was carried out up to the sub-district level.

Results: The incidence rate of measles under five years jumped sharply from 0.64 per 100,000 population (2021) to a peak of 12.50 per 100,000 population (2023), before finally declining in 2024–2025. Confirmed cases are dominated by the age group of 36-59 months (43.8%) and children with unvaccinated status (56.2%). The age group of 24-35 months is the age group that dominates the immunization status who are not immunized with a proportion of 76.5% of children. Measles cases are distributed almost throughout Jambi Province with the highest case burden in Jambi City (Kota Baru and Lake Sipin Districts), Sarolangun Regency (Pelawan District), and Tebo Regency (Rimbo Bujang, Sumay, and Central Tebo Regencies), which is directly proportional to the low local second dose immunization coverage (MR2). Time-based analysis shows a fluctuating pattern of local transmission and there is a tendency for cases to increase in August-October. Excellent specimen condition (97.9% good condition), but experiencing extreme administrative and diagnostic delays (*Turnaround Time / TAT*) with the highest median reaching 101 days in 2023.

Conclusion: The incidence of measles in toddlers aged 0-4 years in Jambi Province for the 2021-2025 period shows an uneven distribution according to people, places, and times. The age group of 36-59 months and cases with no immunization history are the most affected groups, with the concentration of cases in Jambi City, Tebo Regency, and Sarolangun Regency. The increase in incidence in 2023 and the still low coverage of MR2 immunization in several risk areas, accompanied by laboratory turnaround time that has not met standards, shows the need to strengthen the immunization program and measles surveillance system.

Keywords: Epidemiological Distribution; Exploratory Data Analysis; Measles; Surveillance; Jambi Province.

INTRODUCTION

Measles is a highly contagious infectious disease caused by *Morbillivirus*, a member of the *Paramyxovirus* family, with a basic reproduction number (R_0) of 12–18. Transmission occurs through respiratory droplets during coughing or sneezing. Early symptoms include high fever, coryza, conjunctivitis, and Koplik spots on the buccal mucosa, appearing 10–12 days after infection, followed by a maculopapular rash spreading from the face to the rest of the body. Children under five are the most vulnerable group due to their immature immune systems and are at risk of serious complications such as pneumonia, encephalitis, severe diarrhea, and blindness, particularly among unvaccinated or malnourished children (Ministry of Health of the Republic of Indonesia, 2024).

Globally, measles remains a leading cause of childhood mortality. In 2018, more than 140,000 measles-related deaths were recorded worldwide, most occurring in low-income countries with limited immunization coverage. WHO surveillance data from March to September 2025 placed Indonesia among the ten countries with the highest number of measles outbreaks, recording 7,134 cases. A similar trend was observed in high-income countries such as the United States, which reported 1,681 confirmed measles cases in 2025, with most cases occurring in children under five years old. This pattern confirms that measles remains a genuine global health threat, even in high-income countries (Centers for Disease Control and Prevention, 2025).

One of the main drivers of the global resurgence of measles is the substantial decline in immunization coverage during and after the COVID-19 pandemic. WHO and UNICEF reported that globally, in 2022, approximately 20.5 million children missed at least one dose of routine vaccination, an increase from 18.4 million children in 2019, before the pandemic. Coverage of the first dose of measles vaccine only increased from 81% in 2021 to 83% in 2022, still lower than the 86% recorded in 2019. This condition has increased the risk of measles resurgence in various regions, including Indonesia (World Health Organization, 2023; Ota, Badur, Romano-Mazzotti, & Friedland, 2021).

In Indonesia, the impact of declining immunization coverage is reflected in a significant surge in measles cases. According to the Indonesian Health Profile,

suspected measles cases increased from 2.931 in 2021 to 21.175 in 2022, rose further to 39.360 in 2023, and then declined to 25.639 in 2024. Laboratory-confirmed cases were recorded at 132 cases across 71 districts/cities in 25 provinces in 2021; 4,844 cases across 250 districts/cities in 32 provinces in 2022; 10,308 cases across 354 districts/cities in 38 provinces in 2023; and 3,309 cases across 341 districts/cities in 37 provinces in 2024. Children aged 1–4 years accounted for the highest proportion of cases (44.8%), confirming that children under five are the population most affected by measles (Ministry of Health of the Republic of Indonesia, 2022; Ministry of Health of the Republic of Indonesia, 2024). This situation was compounded by an outbreak in 2025 in Sumenep, East Java, with 2,139 suspected cases and 205 laboratory-confirmed cases, most of which occurred in children, with 53% aged 1–4 years (Ministry of Health of the Republic of Indonesia, 2025).

Among the provinces experiencing this surge, Jambi Province was one of the significantly affected regions, having experienced outbreaks of suspected measles in 2022 and 2023 (Kementerian Kesehatan Republik Indonesia, 2023). Data from the Jambi Provincial Health Office showed that the incidence rate of suspected measles rose from 0.55 per 100,000 population in 2021 to 23.66 per 100,000 in 2022, further increasing to 25.05 per 100,000 in 2023, before declining to 6.14 per 100,000 in 2024. Although the discarded rate indicator has met the national standard, this achievement must still be interpreted alongside other indicators, such as data completeness, reporting timeliness, and laboratory testing, to comprehensively reflect surveillance data quality. Laboratory-confirmed surveillance data from 2022 to 2024 show that most cases occurred among children. The 5–9 year age group accounted for the highest proportion in 2022 (40.23%), while in 2023 and 2024 the highest proportion shifted to the 1–4 year age group (33.33% and 34.78%, respectively), reflecting a persistent burden of disease among the youngest and most vulnerable age groups (Jambi Provincial Health Service, 2023; Jambi Provincial Health Service, 2024).

Age is one of the most consistently reported determinants of measles distribution; children under five, particularly those aged 1–4 years, have

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repeatedly shown the highest case proportions both in Indonesia and globally for instance, in Kenya, the 0-4 year age group accounted for 56.3% of cases (1.017 of 1.807 cases) (Ramadhani, Azizah, Jalaludin, Martini, & Sulistyorini, 2023; Ndonge, Ndeti, Nzunza, Kareko, & Limo, 2024). This pattern underscores the importance of describing measles distribution by person, place, and time as a foundation for understanding where and among whom transmission is concentrated.

Several descriptive studies have characterized measles epidemiology by person, place, and time in different parts of Indonesia. A study in Cirebon City (2004-2011) found that most cases occurred in densely populated areas with low immunization coverage, with the highest incidence among unvaccinated children under five. A study in Badung District (2014-2019), using individual-based surveillance data, showed a declining trend in cases, with the highest incidence in Kuta Selatan Subdistrict, among the 5-9 year age group, and predominantly among males. An analysis of Indonesia's national suspected-measles surveillance data (2016-2021) found fluctuating case numbers, with the highest burden in western Indonesia, particularly East Java.

Research on measles specifically in Jambi Province remains limited, particularly studies utilizing comprehensive individual-level surveillance data to describe case distribution by person, place, and time. Prior descriptive studies were conducted in different locations and periods and have not specifically characterized the pattern of measles cases in Jambi Province.

To gain a more comprehensive understanding of these distribution patterns, an Exploratory Data Analysis (EDA) approach can serve as an appropriate analytical method. EDA combines descriptive statistics, pattern exploration, and data visualization to understand the distribution, trends, and anomalies within a dataset (Chandra, 2019). EDA is particularly relevant for health surveillance data, as it allows for the assessment of data quality, detection of missing values and outliers, and exploration of initial patterns prior to further analysis. This approach is also considered highly flexible and well-suited for identifying and investigating phenomena that emerge in empirical research based on secondary data (Behrens, 1997).

RESEARCH METHOD

This study applies an Exploratory Data Analysis (EDA) approach with a descriptive analytical design to systematically analyze measles surveillance data using RStudio software. The EDA process in this study includes eight stages, namely: Understand the data sources and variables contained in the MR02 form, selecting data based on research inclusion and exclusion criteria, checking the data structure and identifying duplicate/duplicate data, perform data cleansing and recoding, assess the completeness of the data and detect abnormal values, create the required derivative variables, including year of occurrence, Time of Completion (TAT), measles case status, immunization status, age group, and fever-rash interval, analyze the distribution of data based on epidemiological variables, namely people, places, and times and visually present findings using tabular instruments, graphs, and distribution maps.

The operational details of the descriptive epidemiological analysis components and the quality of the data of this study are as follows: Data Collection and Selection: Secondary data was obtained from the individual measles-rubella case recapitulation form (MR02) managed by the Immunization Preventable Disease Surveillance Team (PD3I) at the Jambi Provincial Health Office for the 2021-2025 period. The initial population consisted of 456 children aged 0-4 years who were recorded as suspected cases. After going through the data selection process, a final sample of 332 cases that met the criteria was obtained (96 cases of measles were confirmed positive/ambiguous (In accordance with epidemiological surveillance guidelines, cases with unclear IgM laboratory results were grouped together with positive confirmed cases based on the final classification of cases) and 236 cases with negative IgM results). Laboratory System Quality Indicator Analysis: Additional descriptive analysis was carried out on surveillance operational indicators, namely by assessing the physical condition of serum specimens when received in the laboratory and calculating the distribution of Turnaround Time (TAT) (the difference of days from specimen collection to reported results) using boxplot visualization. The status of measles cases itself is determined based on the results of the IgM examination, where positive and unclear results are grouped as positive confirmed cases, while negative results are categorized as negative cases.

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People-Based Analysis: Descriptive statistical analysis and tabulation are used to look at the characteristics of the research subject. The variables explored included clinical symptoms, history of complications, history of hospitalization in the age group (in months), gender, status of measles immunization completeness, history of vitamin A administration, and travel history in the last 1 month.

Place-Based Distribution Analysis: Place distribution was explored in a geographical context in 11 districts/cities in Jambi Province. The analysis was traced to the sub-district level using a visualization of

a case distribution map.

Time and Place-Based Distribution Analysis: This analysis is done specifically by crossing regional variables according to the time dimension. This aims to identify the dynamics of shifts or movements of case waves between regions in Jambi Province during the 5-year observation period and time-Based Distribution Analysis: This distribution is explored to see the trend of case progression over a 5-year period. This stage includes an analysis of the year of occurrence, the epidemic curve, and the trend of cases per month.

RESEARCH RESULTS

Surveillance Data Quality

Table 1. Completeness of Research Data

Variable	Missing value
Districts	9/2.4
Confirmation Date, TAT, Specimen Condition, Travel History	10/3.0
Vitamin A	32/9.6
Cough, red eyes, hospitalized	47/14.2
Cold	171/51.5
Complications	239/72.0
	328/98.8

The data completeness examination showed that the main variables, namely the year of the incident, district/city, age, gender, immunization status, and measles IgM test results, had a good level of completeness. In contrast, a number of supporting clinical variables have a fairly high proportion of unavailable data

Table 2. Consistency of Research Data

Variable	Number of Inconsistent Data (n)
Epidemiological number	4
Date of onset	2
Fever-rash interval	2
Turnaround time (TAT)	1
Regency/city	1

The data consistency check identified five variables with value mismatches, including duplication of epidemiological numbers, onset dates outside the study period, fever-rash intervals with negative values, TAT with negative values, and mismatches between districts/cities and sub-districts. All of these findings have been traced on a case-by-case basis before the analysis stage.

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Measles Surveillance Performance Indicators

The performance indicators for suspected measles surveillance in Jambi Province between 2021 and 2025 demonstrate significant fluctuation, reflecting shifts in system capacity. The discarded rate showed a marked improvement, rising from 0.00 in 2021 to a range of 0.82–22.52 by 2025, with Sungai Penuh and Jambi City leading this trend; conversely, the persistent stagnation in Kerinci and Bungo Regencies suggests localized reporting barriers. While adequacy of case investigations and specimen collection improved significantly post-2021 with many districts achieving 100% adequacy by 2025 the timeliness of specimen results remained at suboptimal levels across most districts. This finding, alongside the trend in laboratory confirmation rates, indicates that accelerating result turnaround times remains a critical priority for strengthening the outbreak response system.

Specimen Conditions and Laboratory Turnaround Time (TAT)

Table 3. Specimen Condition in Confirmed Measles Cases

Specimen Condition	Quantity (n/%)
Good	94/97.9
Not Available	2/2.1
Quantity	96/100

Based on confirmed cases according to specimen conditions, most of the confirmed cases had good specimen condition as many as 94 cases (97.9%) and 2 cases (2.1%) with unavailable specimen conditions.

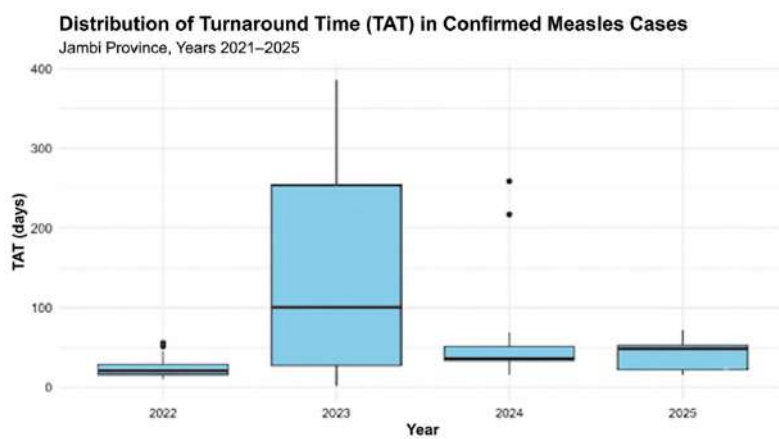


Figure 1. Turnaround Time (TAT) among Confirmed Measles Cases, 2021-2025

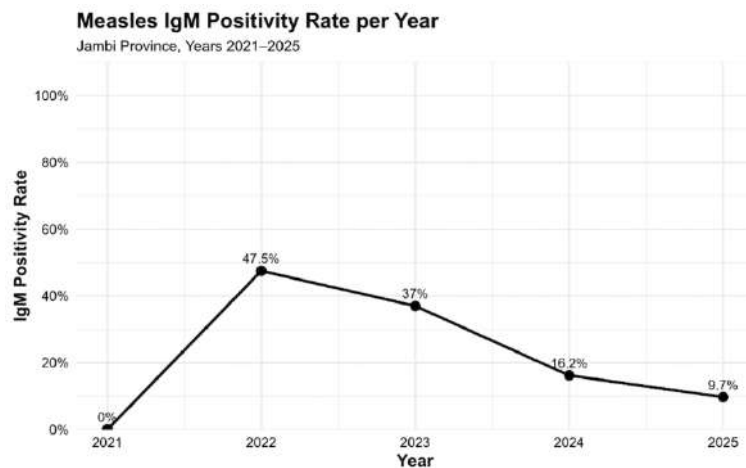
The TAT shows substantial variation throughout the year. The shortest median TAT was recorded in 2022 (21 days; range 10-56 days). The most severe delays occurred in 2023, with a median of 101 days, an average of 134 days, a maximum of 386 days, and the widest IQR (226 days). In 2024, the average TAT decreased to 36.5 days, although the extreme value of 259 days remains. In 2025, the average TAT will be 49 days, with a range of 16-72 days. Outliers are available in 2024 and 2022.

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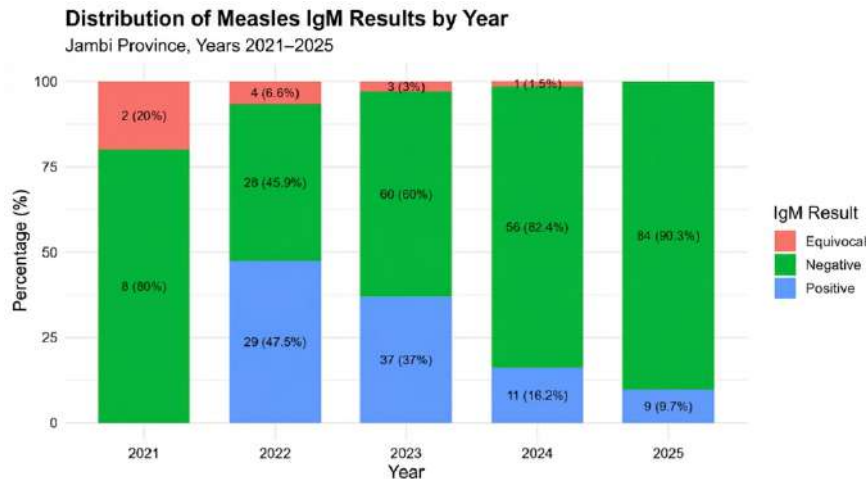
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Figure 2. Positivity Rate

The highest measles IgM Positivity Rate occurred in 2022, then tended to decline until 2025. This decrease suggests that the proportion of suspected measles samples showing lower positive IgM results in recent years. The trend of declining *positivity rate* from 2022 to 2025 is in line with the increase in the *discarded rate indicator* at the district/city level. When health facilities are increasingly active and sensitive in catching suspects of fever-rashes in the community, the proportion of results that come out as positive confirmation of measles will decrease. This proves that the decrease *in the positivity rate* in Jambi Province at the end of the observation year is an indication of improving screening sensitivity as well as a decrease in active transmission in the field.

Figure 3. Measles IgM Results

Confirmed positive cases of measles IgM peaked in the 2022–2023 period, before finally decreasing drastically in the last two years. In contrast, negative results dominated throughout the observation period until reaching 90.3% by 2025, with a final accumulation of 96 positive cases and 236 negative cases.

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Table 4. Description of Clinical Data of Confirmed Measles Cases 2021-2025 (N=96)

Variable	Results
Fever (n/%)	
Yes	96/100
Rash (n/%)	
Yes	96/100
Cough (n/%)	
Yes	16/16.7
No	5/5.2
Missing value	75/78.1
Coryza (n/%)	
Yes	5/5.2
No	4/4.2
Missing value	87/90.6
Red eye (n/%)	
Yes	13/13.5
No	8/8.3
Missing value	75/78.1
Complications (n/%)	96/96
Hospitalization (n/%)	
Yes	15/15.6
No	6/6.2
Missing value	75/78.2
Fever-to-Rash Interval (n/%)	
1-3 days	63/65.6
4-7 days	20/21.0
> 7 days	4/4.0
Same day	7/7.3
Inconsistency	2/2.1

In the cluster of confirmed measles cases, information about clinical symptoms and hospitalized cases has a lot of data that is not available. There were 16 cases of cough symptoms, 5 cases of colds (5.2%), and 13 cases of red eye (13.5%). All complication data is not 100% available. For hospitalized cases, there were 15 cases (15.6%) who were hospitalized. Most confirmed cases (65.6%) develop a rash within 1-3 days of fever, consistent with the clinical profile of measles. As many as 2.1% of cases had an inconsistent date sequence, where the rash date preceded the fever date, which may reflect inaccuracies in the recording.

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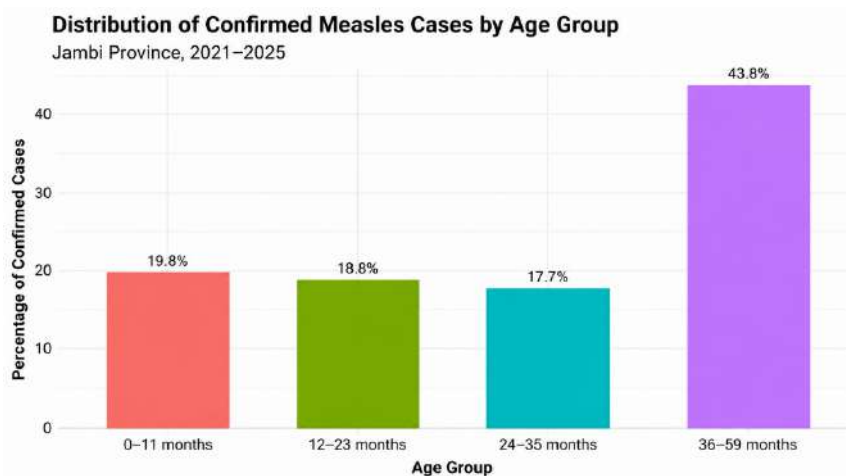
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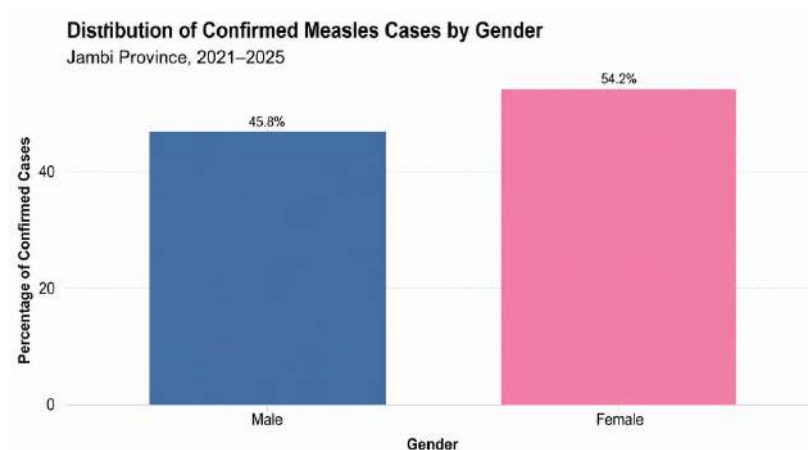
Table 5. Combination of Clinical Symptoms

Symptom Combinations	Quantity (n/%)
Fever + Rash	91/94.8
Fever + Rash + 3C	4/4.2
Fever + Rash + Cough	1/1.0

Based on the symptom combination table, it can be seen that most cases have a combination of fever and rash symptoms without other symptoms recorded as "Yes", i.e. 91 cases or 94.8%. Some cases also had fever and rash + 3C (*cough, coryza, conjunctivitis*) in 4 cases or 4.2%. A combination of fever and rash + cough symptoms was experienced in only 1 case in this group of confirmed cases.

Figure 4. Age Distribution of Measles Cases

Measles cases in Jambi Province in the population aged 0-4 years are dominated by the age group of 36-59 months by 43.8%. Then followed by the age group of 0-11 months of 19.8%, the group of 12-23 months of 18.8%, and the 24-35 months group of 17.7%.

Figure 5. Distribution of Measles Cases by Gender

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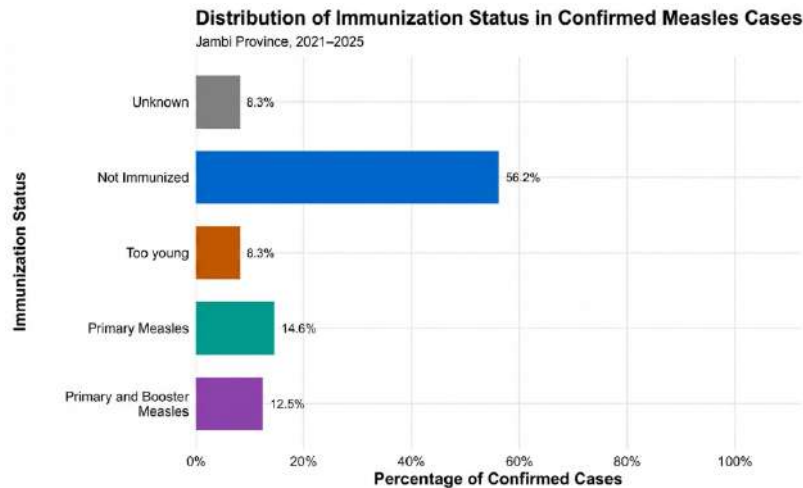
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When viewed from gender, confirmed measles cases are most spread by female gender with a proportion of 54.2% compared to men of 45.8%. The difference in these proportions is not very large and relatively does not differ much between the sexes of women and men.

Figure 6. Distribution of Measles Immunization Status



Based on the graph, it can be seen that cases are dominated by unimmunized status by 56.2%. Followed by the basic immunization group at 14.6%, the basic immunization and booster group at 12.5%, the underage group at 8.3%, and the unknown group at 8.3%.

Table 6. Cross-Tabulation of Age and Immunization Status of Confirmed Measles Cases

Age Group	No Immunization	Basic Measles	Measles & Booster Policy	Immature	Don't know	Quantity (n)
0–11 months	8 (42,1%)	2 (10,5%)	0 (0,0%)	8 (42,1%)	1 (5,3%)	19 (100%)
12–23 months	9 (50,0%)	4 (22,2%)	2 (11,1%)	0 (0,0%)	3 (16,7%)	18 (100%)
24–35 months	13 (76,5%)	1 (5,9%)	3 (17,6%)	0 (0,0%)	0 (0,0%)	17 (100%)
36–59 months	24 (57,1%)	7 (16,7%)	7 (16,7%)	0 (0,0%)	4 (9,5%)	42 (100%)

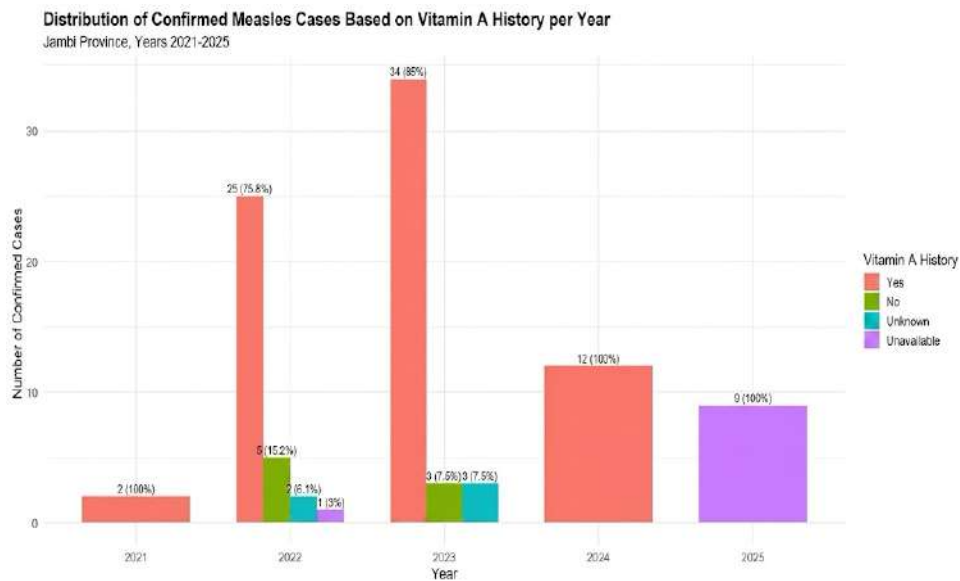
Based on cross-tabulation between the age group and immunization status, it was found that the total case burden was in the age group of 36-59 months. However, in terms of the quality of program coverage in the 24-35 months age group, the level of internal vulnerability is highest because 76.5% of children in that age group have never been immunized at all.

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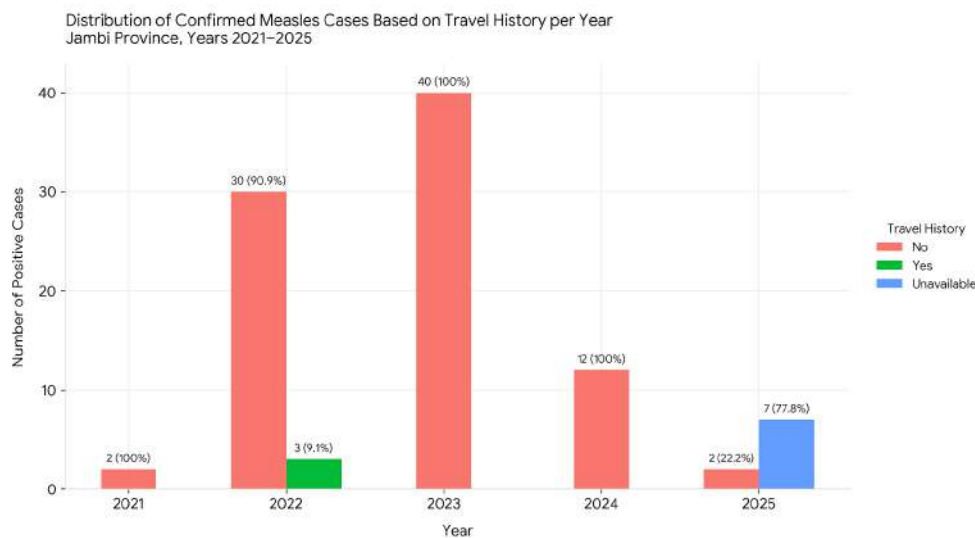
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Figure 7. Distribution of Confirmed Measles Cases by Vitamin A History 2021-2025

The distribution of vitamin A history among confirmed cases shows that most cases in 2022 (75.8%), 2023 (100.0%), and 2024 (100.0%) had a history of vitamin A supplementation. The high proportion of "Yes" may reflect the routine implementation of vitamin A capsule supplementation programs in healthcare facilities.

Figure 8. Distribution of Confirmed Measles Cases by Travel History 2021-2025

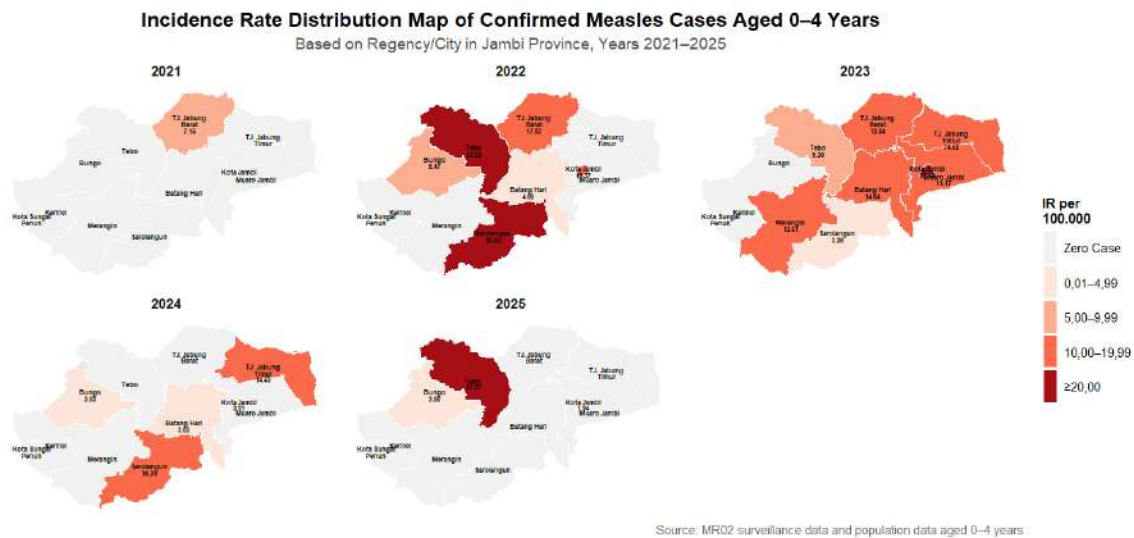
Most confirmed cases have no travel history. In 2021, 2023, and 2024, all cases had no travel history, while in 2022, 3 cases (9.1%) had a travel history.

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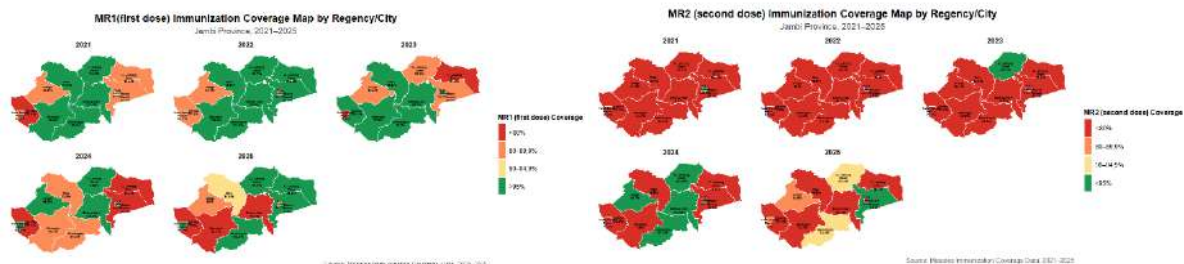
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Figure 9. Map of Measles Case Incidence Map by Regency/City

The distribution of measles incidence rates for toddlers (0-4 years) is uneven and fluctuates from year to year, with the cities of Jambi, Sarolangun, and Tebo contributing to the highest case burden which has reached > 20 per 100.000 population. Meanwhile, the West and East Tanjung Jabung areas also showed a trend of recurrence of events of several years with lower intensity.

Figure 10. MR 1 & MR 2 District/City Immunization Coverage

MR1 immunization coverage in Jambi Province for the 2021–2025 period is very varied and decreased below the target of $\geq 95\%$ in the 2023–2025 period. Kerinci, Bungo, and Jambi City districts were identified as areas that repeatedly failed to meet national targets, underscoring the importance of prioritizing equitable immunization.

Based on the MR 2 coverage map in Jambi Province in 2021–2025, it looks that it is still evenly distributed and most districts/cities have not reached the target of $\geq 95\%$. MR2 coverage looks very low in 2021–2022, then starts to improve in 2024–2025 in some areas. Areas such as Kerinci, Merangin, Tebo, Jambi City, and Tanjung Jabung Timur have low MR2 immunization coverage almost every year.

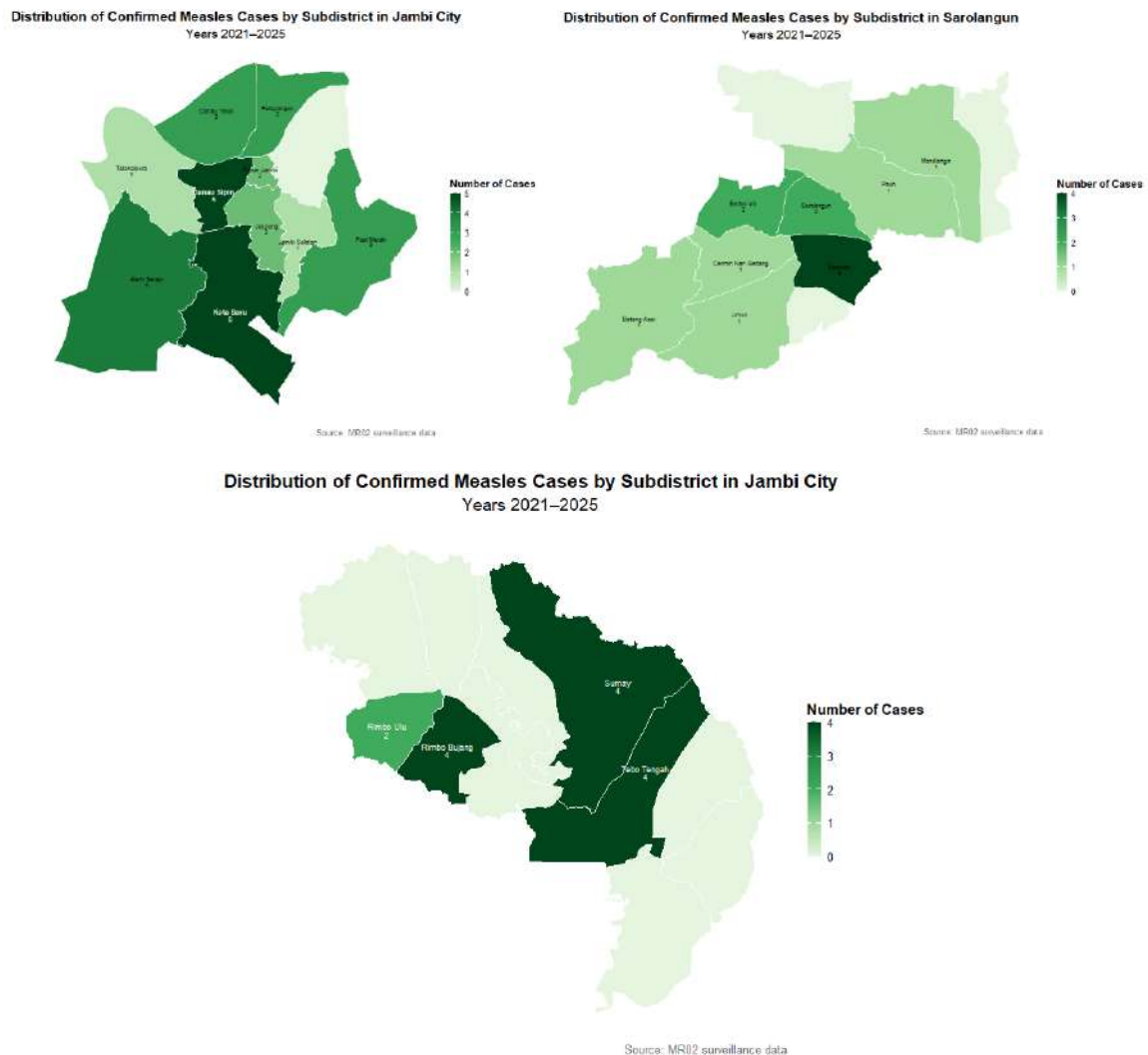
Some areas with high incidence (IR) rates such as Jambi City, Sarolangun, Tebo, and Tanjung Jabung Timur consistently recorded MR2 immunization coverage below the target $\geq 95\%$ even though the first dose (MR1) was mostly adequate. Immunity gaps due to low MR2 achievement were also found in low-incidence areas such as Kerinci and Kota Sungai Penuh.

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Figure 11. Map of the Spread of Measles Cases Based on Jambi, Sarolangun, and Tebo Regencies

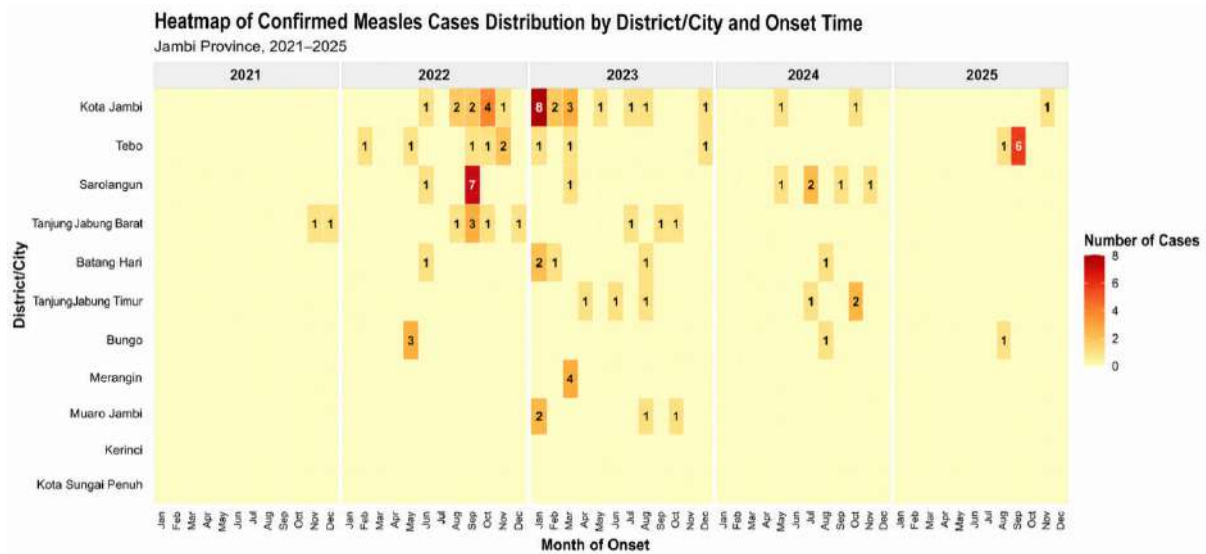
The spread of measles in Jambi City for the 2021–2025 period is concentrated in Sipin Regency, Kota Baru and Danau (5 cases each) and Alam Barajo (4 cases). Although the disease is spreading in almost all areas with a range of 1 to 3 cases in other districts, the accumulated case load remains prominent in certain urban areas. The spread of measles in Sarolangun Regency for the 2021–2025 period is uneven and concentrated in Pelawan Regency with 4 cases. Meanwhile, Bathin VIII and Sarolangun Regencies each recorded 2 cases, followed by five other sub-districts which only reported 1 single case. The distribution of measles cases in Tebo Regency for the 2021-2025 period is uneven and concentrated in Rimbo Bujang, Sumay, and Central Tebo Districts with 4 cases each. Meanwhile, Rimbo Ulu Regency recorded 2 cases, while other sub-districts did not report the findings of confirmed cases.

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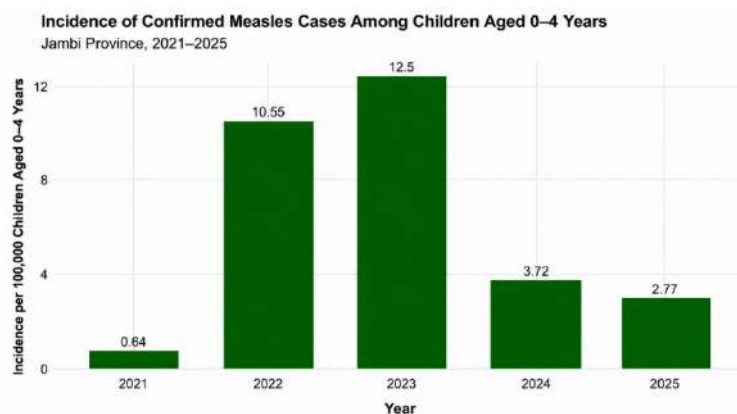
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Figure 12. Trends in Confirmed Measles Cases by District/City and Early Months 2021-2025

The distribution of measles cases by place and time shows that the cities of Jambi, Sarolangun, and Tebo have the most prominent number of cases during the 2021-2025 period. But when viewed by year, the distribution pattern is not always the same.

In 2022, cases appeared in several districts/cities, especially in Sarolangun, Tanjung Jabung Barat, Jambi City, and Tebo. In 2023, the distribution of cases looks more varied with cases appearing in Jambi City, Muaro Jambi, Batang Hari, Merangin, East Tanjung Jabung, and West Tanjung Jabung. In 2025, more cases will be seen in Tebo. This distribution pattern shows that 2022 and 2023 are periods with a wider distribution of cases between districts/cities than other years.

Figure 13. Distribution of Confirmed Measles Cases by Year of Incidence 2021-2025

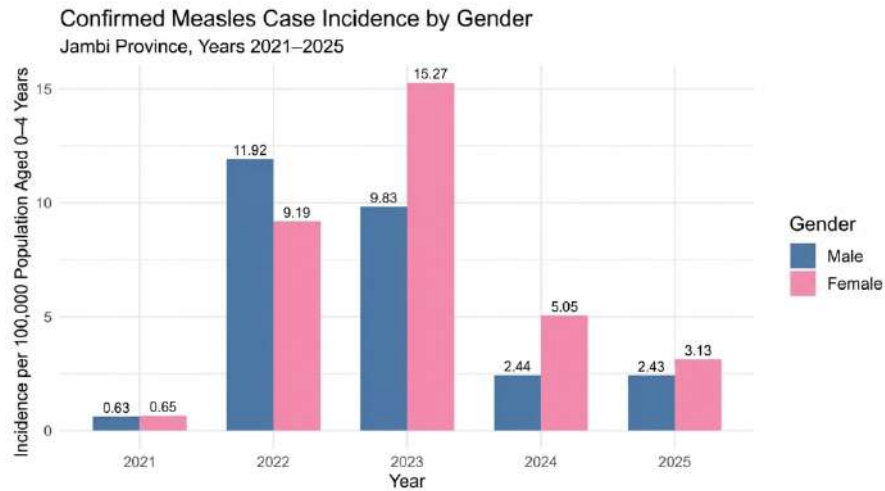
The incidence of measles in toddlers (0-4 years old) in Jambi Province jumped sharply from 0.64 per 100,000 population in 2021 to a peak of 12.50 per 100,000 in 2023. The trend then decreased significantly over the next two years, confirming that the highest incidence burden stood out in the 2022–2023 period.

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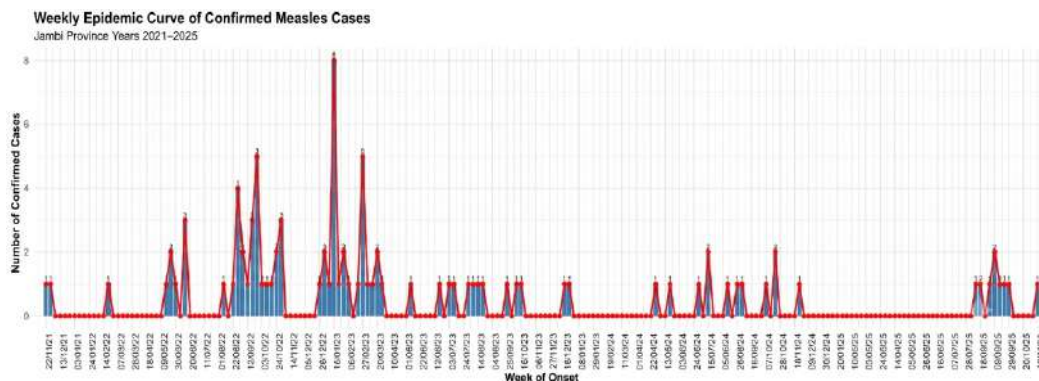
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Figure 14. Incidence of Confirmed Measles Cases by Gender, 2021-2025

The incidence of measles in toddlers by gender shows a similar pattern that peaked in the 2022–2023 period before finally decreasing in the last two years. The inter-gender differences are less striking, with the incidence of the male group being higher in 2022, while the female group was consistently higher throughout the 2023–2025 period.

Figure 2. Epidemi Curve of Confirmed Measles Cases, 2021-2025

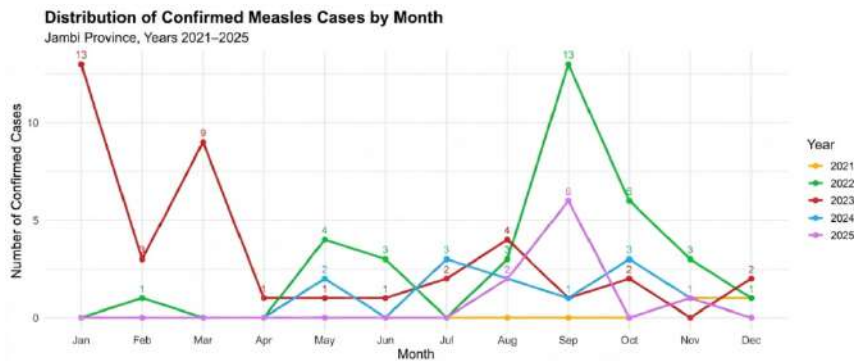
The weekly epidemic curve (2021–2025) shows a fluctuating pattern with multiple recurring peaks indicating the presence of local transmission clusters rather than a single exposure. The most intense transmission activity occurred in mid-2022 to mid-2023 with the highest peak of 8 cases in one week in early 2023. The trend of cases was skewed sporadically in 2024, before finally showing a grouping of mild cases again in the 33rd to 40th weeks in 2025.

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Figure 3. Measles Case Distribution Trends Time by Month, 2021-2025

The monthly distribution (2021–2025) shows the highest concentration of cases in the August–October period with a peak in September (21 cases), in addition to anomalous spikes in January (13 cases) and March (9 cases) in 2023. This increasing trend is proven to be in line with the history of KLB reports (MR05) in Tanjung Barat Jabung (2022) and Jambi City (2023 and 2025). In addition, the KLB document confirms that the majority of infected patients fall into the category of not getting immunized.

The results of this data exploration found that confirmed cases of measles in toddlers aged 0–4 years in Jambi Province for the 2021–2025 period fluctuated with a sharp increase in 2022 until reaching the highest peak in 2023 triggered by a surge in cases at the beginning of the year and a seasonal trend throughout August–October (peak in September) before finally skewing in the 2024–2025 period through an epidemic curve that formed several recurring peaks separated by periods without capital letters. This transmission dynamic is dominated by the group of children aged 36–59 months and those who have not been immunized at all, with a relatively balanced gender proportion between men and women. Spatially, the distribution of cases accumulates unevenly and is concentrated in several main hotspot areas, namely Jambi City (Kota Baru and Lake Sipin Regencies), Sarolangun (Pelawan District), and Tebo (Rimbo Bujang, Sumay, and Central Tebo Regencies), where the high incidence rate in these sub-districts is directly proportional to the low local immunization coverage, especially in the achievement of the second dose (MR2).

DISCUSSION

All confirmed cases presented with fever and maculopapular rash, consistent with the clinical case definition of the Ministry of Health of the Republic of Indonesia (2020). Comorbid symptoms (cough, conjunctivitis, coryza) were rarely recorded, and most other clinical variables were left blank on the MR02 form, indicating that clinical recording completeness in Jambi's surveillance system needs improvement a limitation also reported in Ethiopia, where incomplete data hindered measles control decision making (Endriyas, Solomon, Belayhun, & Mekonnen, 2018).

Children aged 36–59 months dominated confirmed cases, consistent with national data from the Indonesian Ministry of Health in 2024 and previous studies showing that the 1–4 year age group accounted for the majority of cases. Cross-tabulation showed that the 24–35 month age group had the highest proportion of unimmunized children, indicating an immunity gap around the scheduled second dose; this unimmunized group is thought to form a reservoir that subsequently drove the increase in cases in the 36–59 month age group (Ndonye et al., 2024). This reflects patterns elsewhere in Indonesia. A meta-analysis of 23 studies by previous researchers confirmed the status of immunization as a consistent determinant of incidence and associated with service disruptions in the pandemic era (Arianto, Setiawati, Adi, Hadisaputro, & Budhi, 2018; Ramadhani, Azizah, Jalaludin, Martini, & Sulistyorini, 2023).

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As documented by other researchers, the decline in routine immunization globally due to facility closures, reduced visits, and cold chain limitations. In Jambi Province, MR2 coverage never reached the 95% target even though MR1 met the target in 2021–2022, a critical gap because one dose provides an efficacy of approximately 85% compared to nearly 98% with the second dose (Ota, Badur, Romano-Mazzotti, & Friedland, 2021). Other researchers also added that vaccine hesitancy influenced by socio-cultural factors is another contributing factor (Plans-Rubió, P2021; Novilla, Goates, Redelfs, Quenzer, Novilla, Leffler, & Aldridge, 2023).

No significant gender differences were found, suggesting that gender is not a strong predictor here, consistent with research conducted in Central Jakarta; Reports of male predominance elsewhere attributed to hormonal immune differences do not appear to be universal, particularly among toddlers whose exposure is shaped by the family environment rather than independent activities (Kurniasih, A., Lubis, & Damanik, 2024; Nofiyanti, Rahajeng, & Ulfa, 2025; Klein & Huber, 2010). Most cases also had a history of vitamin A supplementation (75.8% in 2022; 100% in 2023–2024), unlike the Bireuen, Aceh study where most cases did not have such a history (Kurniasih, Lubis, & Damanik, 2024). Similarly, most cases had no travel history, suggesting local transmission rather than importation given the limited independent mobility in this age group, in contrast to the South Sumatra study where travel history predominated, likely because it included all ages and not just toddlers (Riantina, Najmah, & Sitorus, 2024).

Disease distribution by place identifies high burden areas via population density, mobility, immunization coverage, health access, and surveillance capacity (Ministry of Health of the Republic of Indonesia, 2022). Jambi City had the highest burden (29 cases, concentrated in Kota Baru and Danau Sipin), reflecting urban density, mobility, and airborne transmission in high interaction settings consistent with Riastini and Sutarga's findings in Bali's high mobility Kuta Selatan District (Riastini, 2021). Tebo (Rimbo Bujang, Sumay, Tebo Tengah) and Sarolangun (Pelawan), though more rural, also carried high burdens, showing transmission depends on combined population movement and geography rather than density alone, tourism based mobility in Pelawan may facilitate importation, while Rimbo

Bujang's transmigration linked mobility with Java, Tebo Tengah's role as government center, and Sumay's geographic isolation (hindering immunization logistics) together create an immunity gap. This indicates that, contrary to the view that density alone drives spread (Riastini, 2021; Nurani, 2012), high mobility rural areas can carry comparable risk.

Some high incidence areas still show below target coverage Jambi City (2022), Tebo (2025), Tanjung Jabung Timur (2023–2024) warranting priority for routine and catch-up immunization, while others (Sarolangun and Tebo 2022, Jambi City 2023) show adequate MR1 but insufficient MR2, indicating high first-dose coverage alone is inadequate, village level coverage equity analysis is recommended. Persistent zero case reporting in Kerinci Regency and Sungai Penuh City, despite expected susceptibility, suggests possible underreporting linked to a low discard rate there. Overall, findings indicate immunization and surveillance should prioritize areas combining low coverage with high incidence, Bayesian cluster analysis is recommended for more precise, region specific risk estimates.

Case concentration shifted across regions and time in September 2022 cases centered on Sarolangun (7) and Tanjung Jabung Barat (3) by early 2023 concentration shifted to Jambi City (8 cases in January, plus Muaro Jambi and Merangin), reflecting broader spread. This coincides with relaxation of pandemic era mobility restrictions (PPKM ended late 2022, WHO lifted the COVID-19 emergency in May 2023, Indonesia declared the endemic transition in June 2023) alongside uneven MR2 coverage across several districts, sustaining susceptibility pockets. This pattern, shaped by connectivity, mobility, density, and uneven immunity, aligns with Isu et al.'s (2016) observation that outbreaks spread between villages within one catchment area and with Nguyen et al.'s finding that measles dynamics follow local coverage, mobility, and inter-regional transmission, as provincial capital, Jambi City likely acts as a source of onward spread. Cases reappeared in Tebo (6 cases, September 2025) after a 2024 decline persistent sub target coverage does not guarantee immediate outbreaks absent external introduction, but yearly accumulation of unimmunized newborns builds susceptibility pockets that sustain circulation once reintroduced (Takahashi, Metcalf, Ferrari,

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Tatem, & Lessler, 2017; Kuylen, Willem, Broeckhove, Beutels, & Hens, 2020).

Annual trends reflect the balance between accumulating susceptibility and immunization response. The sharp 2022 rise, peaking in 2023, aligns with WHO's (2023) projection that pandemic era coverage declines would leave large susceptible cohorts at risk of measles waves; the 2024–2025 decline may reflect improving post pandemic immunization, though continuing cases show immunity remains incomplete.

The August–October peak, especially September, coincides with the dry to rainy transition and matches a documented outbreak in Kampung Nelayan Village, Tanjung Jabung Barat (Aug–Sept 2022), consistent with Wisudariani and Halim's finding that incidence rises with wind speed (Oct–Feb) relevant given Jambi City's strong winds and tornado events as rainfall and humidity may promote transmission via increased indoor crowding among vulnerable children reported a strong humidity incidence correlation in Padang City. A second rise in early 2023 corresponds to an outbreak in Selamat Village, Jambi City (Jan–Mar 2023), suggesting near continuous elevated transmission from late 2022 to early 2023, likely reflecting pandemic related immunization gaps alongside improved post pandemic detection and reporting (Nofiyanti et al., 2025; Rifky, 2024). These findings suggest August–October, especially September, warrants heightened surveillance and readiness, and further STR (Seasonal Trend Decomposition Regression) time series analysis to confirm the seasonal pattern's statistical robustness.

Measles IgM serology remains the cornerstone of laboratory confirmation (Ministry of Health of the Republic of Indonesia, 2020). Positive IgM results predominated throughout (87.9%–100.0% in 2022–2025), indicating specimens were mostly collected within the optimal window (1–2 days to 4–8 weeks post rash), while the 7.5%–12.1% doubtful results in 2022–2024 may reflect suboptimal sampling timing relative to antibody kinetics.

The main systemic challenge was not specimen quality 97.9% (94/96) arrived in good condition but turnaround time (TAT), which rose from 21 days (2022) to 101 days (2023; mean 134, max 386) and remained high in 2024 (36.5 days) and 2025 (49 days), pointing to non-clinical bottlenecks (logistics, reagents, workload, reporting), consistent with South

Sudan surveillance evaluations showing operational and volume pressures can hamper confirmation independent of specimen quality (Kunjok & Zingbondo, 2020). Prolonged TAT undermines early detection, contact tracing, and ring immunization, as confirmation often arrives after outbreaks have progressed indicating collection protocols are effective, but laboratory and reporting logistics need systemic strengthening to support elimination goals.

This study has three main limitations. First, it relies entirely on secondary data from the Jambi Provincial Health Office's routine surveillance system, which inherently has gaps in attribute completeness, the high proportion of missing clinical variables limits this study's ability to build a comprehensive picture of disease severity in children aged 0–4 years. Second, classifying samples with unclear laboratory results as confirmed done to increase surveillance sensitivity in detecting transmission risk carries some risk of including non measles cases due to serological cross-reaction on IgM testing. Finally, the spatial and temporal analysis in this exploratory study remains descriptive and could not statistically control for environmental confounding, population density, or village/sub district level immunization coverage, which is an important direction for future research using more advanced spatial statistical approaches.

CONCLUSION

This study explains that the incidence of measles in toddlers aged 0-4 years in Jambi Province for the 2021-2025 period has an uneven distribution pattern according to people, places, and times. The largest case load was found in toddlers aged 36-59 months who had no history of immunization, with the most critical immune gaps in the 24-35 month age group. Geographically, cases are concentrated in Jambi City, Tebo Regency, and Sarolangun with certain groupings in certain sub-districts, and a number of areas with high incidence rates still record MR02 coverage that has not met the target. The spatial-temporal distribution pattern shows a shift in case concentration between regions related to the dynamics of community mobility and the presence of pockets of vulnerability. The incidence trend peaked in 2023 with a seasonal increase in the August-October period. The quality of surveillance is characterized by good specimen condition, but the far exceeding standard turnaround time (TAT) reflects

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systemic barriers that reduce the operational value of case confirmation in outbreak response.

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