JHE 10 (2) (2025)

Journal of Health Education

http://journal.unnes.ac.id/sju/index.php/jhealthedu

School-Based Immunization, Access to Health Facilities, Breastfeeding, and Vitamin A Supplementation are Correlated with the Incidence of Measles: Ecological Study at the Provincial Level in Indonesia

Lindra Anggorowati[1]✉, Lukman Fauzi[2], Rani Tiara Desty[3]

[1]Department of Pharmacy, Faculty of Medicine, Universitas Negeri Semarang
[2]Department of Public Health, Faculty of Medicine, Universitas Negeri Semarang
[3]Poltekkes Kemenkes Surakarta

Article Info

Article History:
Submitted 01 December 2025
Accepted 21 December 2025
Published 30 December 2025

Keywords:
Measles; Ecological Study; School-Based Immunization; Breastfeeding; Vitamin A Supplementation

DOI
https://doi.org/10.15294/jhe.v10i2. 37568

Abstract

Background: Measles remains a significant public health concern in Indonesia. The number of measles rose sharply from more than 4,800 cases in 2022 to over 10,600 cases in 2023. Objective: This study aimed to analyze the correlation between school-based immunization, access to health facilities, breastfeeding practices, vitamin A supplementation, integrated health post capacity, and the incidence of suspected measles cases at the provincial level in Indonesia.
Methods: An ecological study design was applied using aggregated provincial-level data from the Indonesia Health Profile 2024. Spearman's rank correlation test was used to examine the correlation between some independent variables with measles incidence as dependent variable.
Result: In this study, several variables showed significant negative correlations with measles incidence of measles. Variables with significant correlations at p value<0.005 were number of children receiving school immunization (ρ =-0.930), number of regencies achieving 80% complete basic immunization (ρ=-0.730), number of students accessing health facilities (ρ=-0.798), number of babies receiving exclusive breastfeeding (ρ = -0.826) number of children receiving booster measles immunization (ρ=-0.659), number of babies receiving vitamin A (ρ=-0.505) and number of children under five receiving vitamin A (ρ=-0.477). Meanwhile, variables related to number of regencies receiving integrated health post training and activity levels 80% of active integrated health post did not show significant correlations with the incidence of measles (p value>0.05).
Conclusion: It can be concluded that school-based immunization, access to health facilities, breastfeeding, and vitamin A supplementation are correlated with the incidence of measles at the provincial level in Indonesia

✉ Correspondence Address:
Email : lindranggorowati@mail.unnes.ac.id

p-ISSN 2527-4252
e-ISSN 2528-2905

INTRODUCTION

Measles remains one of the most contagious viral diseases and continues to pose a major public health challenge worldwide. Despite the availability of safe and effective vaccines for over five decades, global progress toward measles elimination has been uneven, with persistent subnational inequalities threatening control efforts (Utazi et al., 2019). Global health authorities, including the World Health Organization (WHO) and UNICEF, emphasize the necessity of maintaining high vaccine coverage, especially two doses to achieve elimination targets and prevent resurgence (World Health Organization, 2020, 2021, 2025). Recent years have witnessed concerning reversals in immunization coverage and measles control. Global measles cases increased substantially from an estimated 8.6 million in 2022 to 10.3 million in 2023, with the first-dose measles-containing vaccine (MCV1) coverage stagnating at approximately 83% during 2022–2023, following a pandemic-era nadir of 81% in 2020. These coverage gaps have resulted in large-scale outbreaks concentrated predominantly in low-income and fragile settings, with the number of affected countries rising markedly (Minta et al., 2024). Regional disparities remain stark, Southeast Asia experienced notable measles surges in 2022–2023, driven largely by immunity gaps accumulated during the COVID-19 pandemic disruptions (Chacko et al., 2023; Zaini et al., 2023).

Indonesia, the world's fourth most populous nation with substantial geographic and socioeconomic heterogeneity, has faced considerable challenges in sustaining measles control. National surveillance data reveal declining routine immunization coverage during 2013–2022, with MCV1 coverage falling from 87% to 84% and second-dose MCV (MCV2) coverage decreasing from 76% to 67% (Chacko et al., 2023). The COVID-19 pandemic severely disrupted routine immunization services, precipitating a dramatic measles resurgence in 2022 when the incidence of measles surged to approximately 29 cases per million population from 1.4 per million in 2021 (Chacko et al., 2023; Shariff et al., 2023). This resurgence necessitated emergency response measures, including a nationwide measles-rubella supplementary immunization activity (SIA) in 2022 that reached approximately 26 million children across 32 provinces (Chacko et al., 2023). Similar pandemic-related disruptions and subsequent measles outbreaks have been documented in neighboring countries, including India and Nepal, underscoring regional vulnerabilities in routine immunization systems (Sethi et al., 2023; Thakur et al., 2024).

The decline vaccine confidence during COVID-19 pandemic in Indonesia affected national immunization targets. Fully immunized children coverage for infants aged 0-11 months reached 84.2 per cent in 2020 and 84.5 per cent in 2021 (under 92%). The number of zero-dose children rose from 10 per cent in 2019 to 26 per cent in 2021 (UNICEF Indonesia, 2022, 2023). This situation has resulted in an increase in measles cases. In 2022, more than 4,800 confirmed measles cases were recorded. This number increased in 2023 to more than 10,600 cases. In 2024, it decreased to just over 3,500 cases, but increased again in 2025, with more than 3,400 cases recorded by August 2025. Measles outbreaks have occurred in several regions, with 64 reported in 2022, then increasing to 95 in 2023. This then decreased to 53 in 2024, but increased again in 2025, with 46 recorded by August 2025 (Ministry of Health of Indonesia, 2025)

In many settings in Indonesia, health system disruptions, inequity of service distribution, vaccine hesitancy, and surveillance gaps have made immunization less effective at preventing measles spread. Routine immunization coverage declined in multiple districts during the pandemic and the number of children who have never received any routine vaccine ("zero-dose" children) increased, especially in a condition concentrated among hard-to-reach and disadvantaged communities. Subnational disparities (urban vs rural and remote island provinces), weaknesses in surveillance and cold-chain management, and periodic lapses in outbreak responsiveness have contributed to persistent susceptibility in parts of the country (UNICEF Indonesia, 2022, 2023)

Subnational heterogeneity in vaccination coverage represents a critical determinant of measles outbreak risk and persistence. Wide

district- and state-level variations in MCV1 coverage and timely vaccination have been documented across South and Southeast Asia, with socioeconomic gradients, maternal health service utilization, and urban-rural disparities explaining substantial proportions of this variation (Panda et al., 2020). In Indonesia, a systematic review and meta-analysis identified key risk factors for the incidence of measles including incomplete immunization status, inadequate health facility access, poor nutritional status, low maternal education, and household crowding (Ramadhani et al., 2023). Subnational outbreak investigations have consistently revealed clustering of cases among unvaccinated or under-vaccinated children in specific geographic areas, including high-density urban slums and underserved rural districts (Sethi et al., 2023; Zaini et al., 2023). These findings highlight the critical need for subnational ecological analyses to identify immunity gaps and inform targeted intervention strategies.

Multiple delivery platforms contribute to measles immunization coverage, each with distinct strengths and challenges. Routine facility-based immunization services remain the backbone of vaccination programs, with health facility access and maternal antenatal care utilization serving as strong predictors of MCV1 receipt and timeliness (Panda et al., 2020). However, facility-based services alone may not reach all vulnerable populations, particularly in remote areas or among marginalized communities. School-based immunization programs represent a complementary strategy for reaching older children who may have missed routine infant vaccinations, thereby closing immunity gaps at school entry (Oteri et al., 2023). In Indonesia, community-based integrated health services delivered through Posyandu (integrated health posts) serve as critical contact points for maternal-child health services, including immunization, growth monitoring, and nutrition supplementation. Despite their widespread presence, the contribution of Posyandu activities to routine vaccine-preventable disease surveillance and immunization coverage remains under-evaluated and potentially under-utilized (Fahriani et al., 2025).

Nutritional status plays an important role in measles risk, disease severity, and vaccine response. Vitamin A deficiency increases the chances of severe measles and death. A large review of clinical trials showed that giving vitamin A to children aged 6–59 months can reduce the incidence of measles by 50% and lower overall mortality. Modeling studies also indicate that mass nutrition programs can improve children's nutrition, increase contact with health services, boost vaccination coverage, and significantly reduce measles cases and deaths. Breastfeeding also supports better vaccine response; an Indonesian study found that breastfeeding and vitamin A supplementation were linked to stronger immune responses after the first measles vaccine dose (Imdad et al., 2022; Noori et al., 2022; Nurlatifah et al., 2021).

Effective measles control needs strong surveillance systems to quickly detect outbreaks and find areas with low immunization. But many low- and middle-income countries, including Indonesia, still struggle with weak surveillance and poor data integration. Different data sources such as routine immunization reports, case surveillance, and population surveys—are often stored separately, making it difficult to see local immunity gaps. To address this, experts recommend data triangulation, which combines these data sources to identify zero-dose and under-immunized children and guide targeted interventions at the subnational level. (Rachlin et al., 2024). Community-based surveillance for vaccine-preventable diseases remains limited in current Indonesian practice, despite the potential of Posyandu and other community platforms to contribute to early outbreak detection and response (Fahriani et al., 2025)

The convergence of documented subnational immunization inequalities, COVID-19-related service disruptions, measles resurgence in Indonesia, and incomplete understanding of factors associated with provincial measles incidence creates a compelling rationale for ecological analysis at the provincial level. While individual-level risk factors have been identified through meta-analysis (Ramadhani et al., 2023), the relationships between provincial-level

immunization delivery platforms (school-based immunization, health facility access, Posyandu activity), nutritional factors (breastfeeding prevalence, vitamin A supplementation coverage), and the incidence of measles remain incompletely characterized. Such ecological analysis can inform evidence-based targeting of integrated program interventions and guide data triangulation efforts for routine program monitoring.

Understanding these determinants is essential to strengthen Indonesia's public health strategies and accelerate progress toward controlling and eliminating measles. While Indonesia has committed to achieving universal health coverage and to meeting the Sustainable Development Goals (SDGs), the gap between immunization policy goals and realized coverage remains and outbreaks continue to pose risks. Therefore, the aims of this study to quantify provincial-level ecological associations between the incidence of measles and key programmatic and nutritional factors in Indonesia, specifically: (1) number of children receiving school immunization, (2) number of regencies achieving 80% complete basic immunization, (3) number of children receiving booster measles immunization, (4) number of students accesing health facilities, and (5) number of babies receiving early initiation of breastfeeding, (6) number of babies receiving exclusive breastfeeding, (7) number of children under five receiving vitamin A, (8) number of regencies receiving integrated health post training, (9) number of regencies at least 80% of active integrated health post. Additionally, the study seeks to identify provinces with clustering of low coverage indicators and high the incidence of measles to prioritize integrated program responses and inform subnational decision-making for measles elimination efforts.

METHODS

This study employed a quantitative ecological. The unit of analysis was the province, and all variables were aggregated at the provincial level from Indonesian Health Profile 2024. Data were analyzed using Spearman's rank correlation to assess the statistical association between the incidence of measles and the selected provincial-level determinants. The dependent variable was the number of measles suspects, while the independent variables included: number of children receiving school immunization, number of regencies achieving ≥80% complete basic immunization, number of children receiving booster measles immunization, number of students accesing health facilities, number of babies receiving early initiation of breastfeeding, number of babies receiving exclusive breastfeeding, number of babies receiving vitamin A, number of children under five receiving vitamin A, number of regencies receiving integrated health post training (posyandu), and number of regencies with ≥80% active integrated health posts. All variables were ranked, and Spearman's correlation coefficient (ρ) was computed to determine the direction and strength of associations. Statistical significance was assessed using a two-tailed test with a significance level of $p < 0.05$. The results were presented in correlation tables and interpreted to identify key factors associated with the incidence of measles at the provincial scale.

RESULTS AND DISCUSSIONS

Table 1 presents the descriptive statistics and normality assessment of all variables included in this study. The dataset comprised 34 provinces in Indonesia, with the incidence of measles as the dependent variable and ten independent variables representing various health indicators.

The descriptive analysis revealed substantial variability across all measured variables. The dependent variable, the incidence of measles, demonstrated a mean of 622.79 cases (SD = 859.68), with values ranging from 16 to 2,955 cases. The considerable standard deviation, exceeding the mean value, indicates substantial heterogeneity in measles burden across Indonesian provinces. The median value (202.0) was notably lower than the mean, suggesting a right-skewed distribution with several provinces experiencing disproportionately high the incidence of measles.

Table 1. Data distribution of the variables studied

Variables	Mean	SD	Median	Minimum	Maximum	p-value (Shapiro-Wilk)	Distribution (α=0.05)
Number of measles suspects	622.79	859.68	202	16	2955	<0.001	Non-normal
Number of children receiving school immunization	122508	178722	62598.5	11010	819700	<0.001	Non-normal
Number of regencies achieving 80% complete basic immunization	8.53	8.31	6	1	36	<0.001	Non-normal
Number of children receiving booster measles immunization	113674	171792	46617.5	8995	779625	<0.001	Non-normal
Number of students accesing health facilities	4157.03	5320.19	2505.5	249	21898	<0.001	Non-normal
Number of babies receiving early initiation of breastfeeding	87866.1	136087	44250	3200	715420	<0.001	Non-normal
Number of babies receiving exclusive breastfeeding	77007.3	122046	32464	1523	624248	<0.001	Non-normal
Number of babies receiving vitamin A	89531.3	135982	45364	6587	680715	<0.001	Non-normal
Number of children under five receiving vitamin A	361201	553425	163146	17100	2750937	<0.001	Non-normal
Number of regencies receiving integrated health post training	9.97	8.21	8	1	37	<0.001	Non-normal
Number of regencies at least 80% of active integrated health post	7.35	4.67	7	1	21	0.006	Non-normal

Among the immunization-related variables, school immunization coverage showed a mean of 122,508.35 children (SD = 178,721.80), while measles-specific immunization averaged 113,674.26 children (SD = 171,791.84). The high standard deviations relative to means in both variables reflect considerable inter-provincial disparities in immunization program reach, likely influenced by population size and program implementation effectiveness. The basic immunization coverage across regencies in 2020 had a mean of 8.53 (SD = 8.31), with values ranging from 1 to 36 regencies, reflecting varying levels of primary healthcare infrastructure maturity across provinces.

Healthcare access, measured by the number of health facilities, averaged 4,157.03 facilities per province (SD = 5,320.19), ranging from 249 to 21,898 facilities. This wide range underscores the substantial infrastructure gap between provinces, with the median (2,505.5) again falling below the mean, indicating that a majority of provinces have below-average healthcare facility coverage.

Breastfeeding indicators showed considerable variation. Early initiation of breastfeeding (EIB) averaged 87,866.09 infants (SD = 136,087.19), while exclusive breastfeeding (EBF) for six months averaged 77,007.26 infants (SD = 122,045.63). The high standard deviations suggest significant provincial differences in breastfeeding practices and health education program effectiveness.

Vitamin A supplementation programs demonstrated high coverage, with vitamin A for babies distribution averaging 89,531.32 children (SD = 135,982.10) and vitamin A for children under five reaching 361,200.59 children (SD = 553,424.86). The substantially higher mean for vitamin A for children under five compared to vitamin A for babies aligns with the broader age range targeted in the second distribution phase.

The Integrated Health Post (Posyandu) indicators showed relatively lower variability. IHP training in regencies averaged 9.97 (SD = 8.21), while active IHP averaged 7.35 (SD = 4.67).

The Shapiro-Wilk test was employed to assess the normality of distribution for all variables, given its superior power for sample

sizes less than 50 (Razali & Wah, 2011). The results revealed that none of the variables followed a normal distribution at the α = 0.05 significance level. All variables yielded p-values below the critical threshold ($p < 0.05$), with most demonstrating highly significant departures from normality ($p < 0.001$).

Table 2. Spearman correlation analysis between independent variables and the incidence of measles in Indonesian Provinces

Independent Variable	Spearman ρ	p-value	Interpretation
Number of children receiving school immunization	-0.930	<0.001***	Negative, Very Strong
Number of regencies achieving 80% complete basic immunization	-0.730	<0.001***	Negative, Very Strong
Number of children receiving booster measles immunization	-0.659	<0.001***	Negative, Strong
Number of students accesing health facilities	-0.798	<0.001***	Negative, Very Strong
Number of babies receiving early initiation of breastfeeding	-0.669	<0.001***	Negative, Strong
Number of babies receiving exclusive breastfeeding	-0.826	<0.001***	Negative, Very Strong
Number of babies receiving vitamin A	-0.505	0.002**	Negative, Strong
Number of children under five receiving vitamin A	-0.477	0.004**	Negative, Moderate
Number of regencies receiving integrated health post training	0.275	0.116	Positive, Weak (ns)
Number of regencies at least 80% of active integrated health post	0.323	0.062	Positive, Moderate (ns)

Note: ** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ns = not significant ($p \geq 0.05$)*

Table 2 presents the results of Spearman's rank correlation analysis examining associations between the incidence of measles and ten health system factors across 34 Indonesian provinces. Given the non-normal distribution of all variables (as demonstrated in Table 1), Spearman's correlation coefficient (ρ) was employed as the appropriate non-parametric measure of association.

The analysis revealed that eight of ten independent variables (80%) demonstrated statistically significant correlations with the incidence of measles at the $\alpha = 0.05$ level. Notably, all significant correlations exhibited negative directionality, indicating that higher levels of health interventions and service coverage were associated with lower of the incidence of measles. The strength of associations ranged from moderate to very strong, with correlation coefficients spanning from $\rho = -0.477$ to $\rho = -0.930$.

Four variables demonstrated very strong negative correlations with the incidence of measles. Number of children receiving school immunization showed the strongest association ($\rho = -0.930$, $p < 0.001$), indicating that provinces with higher numbers of school children receiving immunization experienced substantially lower measles burden. This exceptionally strong correlation underscores the critical protective role of comprehensive school-based immunization programs in measles control. This finding aligns with recent global and subnational evidence demonstrating that high vaccination coverage is the most critical determinant of measles control. Wang et al. (2022) reported that global declines in the incidence of measles were predominantly driven by increased measles-containing vaccine (MCV) coverage, with low socio-demographic index regions exhibiting both higher incidence and lower coverage. Similarly, subnational analyses from Nigeria revealed significant negative correlations between state-level the incidence of measles and first-dose MCV coverage, highlighting substantial geographic variability in outbreak patterns (Sato et al., 2022).

The number of regencies achieving 80% complete basic immunization showed a very strong negative correlation ($\rho = -0.730$, $p < 0.001$), demonstrating that provinces with more regencies meeting immunization coverage targets experienced lower measles burden. This metric serves as a proxy for immunization program maturity and geographic equity within provinces. Recent evidence from Ghana's Savannah Region demonstrated that declining

measles-rubella (MR) vaccination coverage from 2019 onwards was associated with a sharp increase in confirmed measles cases, with moderate to strong negative correlations between MR coverage and incidence (Adjei et al., 2024). These findings support the WHO recommendation of maintaining at least 95% coverage with two doses of MCV to interrupt measles transmission and achieve elimination goals (World Health Organization, 2017).

The strong negative correlation between booster measles immunization and incidence ($\rho = -0.659$, $p < 0.001$) highlights the critical role of two-dose vaccination schedules. A recent outbreak investigation in a highly vaccinated French middle school demonstrated that vaccine effectiveness reached 96.4% when the first dose was administered at ≥12 months of age followed by an appropriately timed second dose, compared to significantly lower effectiveness when the first dose was given earlier (Antona et al., 2025). This two-dose strategy is essential because it addresses primary vaccine failure (failure to seroconvert after the first dose) and secondary vaccine failure (waning immunity over time), thereby reducing the susceptible pool and interrupting transmission chains (Antona et al., 2025; Wang et al., 2022).

The biological mechanism underlying these strong correlations is well-established: measles vaccination induces neutralizing antibodies and cell-mediated immunity that provide long-lasting protection against infection. Two-dose schedules increase the proportion of children who achieve and sustain protective antibody levels, creating herd immunity that protects both vaccinated individuals and those who cannot be vaccinated (Moss, 2017). Mathematical modeling from India has projected that achieving very high first-dose coverage (>95%) could lead to measles elimination, with steep declines in incidence associated with incremental improvements in coverage (Verguet et al., 2015).

Number of students accesing health facilities exhibited a very strong negative correlation ($\rho = -0.798$, $p < 0.001$), indicating that provinces with greater healthcare infrastructure accessibility achieved lower of the incidence of measles. This finding highlights the importance of healthcare access in facilitating timely immunization, early case detection, and prompt treatment. This finding is consistent with recent evidence from Iraq, where subnational variation in the incidence of measles was strongly influenced by health service delivery, population displacement, and access constraints (Comfort et al., 2022). It was found that Iraqi governorates with higher proportions of displaced persons experienced elevated measles incidence even when vaccination coverage estimates were comparable, illustrating how access barriers and population mobility drive subnational outbreaks.

Access to health facilities facilitates not only routine immunization delivery but also timely case detection, outbreak response, and vitamin A supplementation during measles illness. Limited geographic or economic access reduces opportunities for preventive services and delays treatment-seeking behavior, thereby increasing the size of the susceptible population and prolonging transmission during outbreaks (Comfort et al., 2022; Utazi et al., 2019). In the Indonesian context, where geographic diversity ranges from densely populated urban centers to remote island communities, ensuring equitable access to health facilities is paramount for achieving uniform vaccination coverage and rapid outbreak control.

The study revealed very strong and strong negative correlations between exclusive breastfeeding ($\rho = -0.826$, $p < 0.001$) and early initiation of breastfeeding ($\rho = -0.669$, $p < 0.001$) with the incidence of measles. These suggest that provinces with higher rates of six-month exclusive breastfeeding and early initiation of breastfeeding experienced significantly lower measles incidence. While breastfeeding does not directly prevent measles infection, it enhances infant immune function and overall health status, potentially reducing measles susceptibility and severity (Duijts et al., 2010). These findings suggest that optimal breastfeeding practices may play a significant protective role against measles at the population level. Exclusive breastfeeding for the first six months of life provides passive immunity through maternal antibodies in breast milk, supports the development of the infant's

immune system, and reduces overall morbidity from infectious diseases (Victora et al., 2016).

The biological mechanism linking breastfeeding to reduced measles susceptibility operates through multiple pathways. First, breast milk contains measles-specific IgA antibodies that provide passive mucosal immunity during the period before active immunization (Hanson et al., 2003). Second, breastfeeding supports the maturation of the infant's immune system, enhancing responses to vaccination and natural infections (Victora et al., 2016). Third, exclusive breastfeeding reduces exposure to contaminated water and food, thereby lowering the overall infectious disease burden and improving nutritional status, which in turn supports immune function (Hanson et al., 2003; Victora et al., 2016).

Early initiation of breastfeeding within the first hour of life is associated with improved neonatal survival and establishes successful breastfeeding practices that may continue for months (Smith et al., 2017). The strong negative correlation observed in this study suggests that provinces with higher rates of early breastfeeding initiation also have better maternal and child health practices more broadly, which may contribute to lower measles incidence through multiple pathways including higher vaccination coverage and better nutritional status.

The study identified significant negative correlations between vitamin A supplementation and the incidence of measles for both babies ($\rho = -0.505$, $p = 0.002$) and children under five ($\rho = -0.477$, $p = 0.004$). While these correlations are statistically significant, the moderate strength suggests a complex relationship that warrants careful interpretation. Global burden of disease analyses have consistently identified vitamin A deficiency as a major contributor to measles mortality and severe complications, supporting the biological plausibility of this association (Imdad et al., 2017; Wang et al., 2022).

The mechanism by which vitamin A influences measles outcomes is well-documented: vitamin A deficiency impairs epithelial barrier function, reduces immune cell proliferation and antibody responses, and increases susceptibility to secondary infections (Imdad et al., 2017). The WHO recommends vitamin A supplementation for all children diagnosed with measles in areas where vitamin A deficiency is a public health problem, as supplementation has been shown to reduce measles mortality by approximately 50% (World Health Organization, 2011). However, it is important to note that vitamin A supplementation primarily reduces disease severity and mortality rather than preventing infection per se, which may explain why the correlations with incidence are moderate rather than very strong (Wang et al., 2022).

A provincial-level analysis from East Java, Indonesia, found a negative but statistically non-significant correlation between vitamin A coverage and measles cases indicating mixed results across different Indonesian provinces (Sari & Astutik, 2024). This heterogeneity suggests that the relationship between vitamin A supplementation and measles incidence may be modified by other factors such as baseline nutritional status, supplementation coverage and timing, and the presence of other interventions. The provincial-level correlations observed in the present study should therefore be interpreted as reflecting the combined effects of improved nutritional status, enhanced immune function, and the programmatic quality of child health services that deliver both vitamin A and routine immunizations.

Interestingly, the study found non-significant correlations between the incidence of measles and both the number of regencies receiving integrated health post training ($\rho = 0.275$, $p = 0.116$) and the number of regencies with at least 80% active integrated health posts ($\rho = 0.323$, $p = 0.062$). The weak positive direction of these correlations, though not statistically significant, warrants careful interpretation.

One plausible explanation for these unexpected findings is reverse causation: areas experiencing measles outbreaks may receive prioritized training and mobilize more active health posts as part of outbreak response efforts, creating a positive ecological association between service activity and incidence when measured cross-sectionally (Adjei et al., 2024; Patel et al., 2021). Adjei et al. (2024) documented reactive vaccination efforts following declining coverage and rising measles cases in Ghana's Savannah Region, illustrating how programmatic responses to outbreaks can

confound cross-sectional analyses of service indicators. Similarly, surveillance studies from Nigeria have documented intensified catch-up vaccination activities following outbreaks, which would produce positive correlations if activity levels and incidence are measured simultaneously (Sato et al., 2022).

A second explanation relates to the quality versus quantity of services: the mere presence of training or active health posts does not guarantee effective service delivery. Heterogeneity in the quality of immunization services, cold chain maintenance, health worker knowledge, and community engagement may result in weak or null associations between structural indicators and health outcomes (Arsenault et al., 2018). The integrated health post system (Posyandu) in Indonesia relies heavily on community volunteers, and the effectiveness of these posts varies considerably depending on volunteer training, supervision, community participation, and integration with the formal health system (Pangaribuan et al., 2020).

Third, measurement error and ecological fallacy may contribute to the non-significant findings. Regency-level indicators may not adequately capture the population coverage or quality of services experienced by individuals, and aggregation to the provincial level for correlation analysis may further obscure true relationships (Morgenstern, 1995). Additionally, the cross-sectional design cannot establish temporal relationships, making it impossible to determine whether training and health post activation preceded or followed changes in the incidence of measles.

Finally, the moderate positive correlation for active health posts ($\rho = 0.323$) approaching statistical significance ($p = 0.062$) may reflect surveillance intensity bias: provinces with more active health posts may have better case detection and reporting systems, leading to higher recorded incidence even if true disease burden is similar or lower (Durrheim et al., 2021). This phenomenon has been documented in other surveillance contexts where improved reporting systems paradoxically increase recorded disease incidence.

The findings of this study have several important implications for measles control strategies in Indonesia. First and foremost, the exceptionally strong correlations between immunization coverage indicators and the incidence of measles underscore the critical importance of maintaining and restoring high two-dose MCV coverage. The COVID-19 pandemic disrupted routine immunization services globally, creating immunity gaps that have led to measles resurgences in multiple countries (Moraga-Llop et al., 2021; Shet et al., 2022). Indonesia must prioritize catch-up vaccination campaigns targeting cohorts that missed routine immunizations during the pandemic, with particular attention to school-aged children and hard-to-reach populations.

Second, the very strong correlation between health facility access and the incidence of measles highlights the need for continued investment in health system infrastructure and outreach services. Strategies should include mobile vaccination teams for remote areas, school-based immunization programs, and integration of measles vaccination with other child health services to maximize coverage (Comfort et al., 2022; Gavi, the Vaccine Alliance, 2020). Special attention should be given to displaced populations, urban slums, and other marginalized communities that face barriers to accessing routine health services.

Third, vitamin A supplementation should be maintained as an essential component of measles case management and preventive child health programs. While the moderate correlations suggest that vitamin A supplementation alone is insufficient to control measles transmission, it remains a critical intervention for reducing severe disease and mortality, particularly in areas with high rates of malnutrition (Imdad et al., 2017; World Health Organization, 2011). Integrated delivery of vitamin A supplementation with routine immunizations through platforms such as integrated health posts can improve coverage of both interventions.

Fourth, the strong correlations with breastfeeding practices suggest that promoting optimal infant feeding may contribute to measles control as part of comprehensive maternal and child health strategies. Programs should continue to support early initiation and exclusive breastfeeding through healthcare

provider training, community education, and policies that protect breastfeeding in healthcare facilities and workplaces (Smith et al., 2017; Victora et al., 2016). However, given the lack of direct recent evidence linking breastfeeding to the incidence of measles, targeted research is needed to validate these associations and identify the specific mechanisms and pathways involved before making major programmatic shifts based solely on these correlations.

Finally, the non-significant findings for integrated health post indicators suggest the need for longitudinal program evaluation using process and outcome measures collected over time rather than relying on cross-sectional snapshots. Future research should employ time-series analyses, interrupted time series designs, or cohort studies to disentangle the effects of programmatic responses from true preventive impact (Bernal et al., 2017). Quality improvement initiatives should focus not only on training and activation of health posts but also on ensuring high-quality service delivery, adequate supervision, cold chain maintenance, and community engagement.

This study benefits from the use of provincial-level data across Indonesia, providing insights into the determinants of the incidence of measles in a large, geographically diverse, and middle-income country context. The inclusion of multiple domains of intervention—immunization, nutrition, breastfeeding, and health systems—allows for a comprehensive assessment of factors associated with measles control.

However, several limitations should be acknowledged. First, the ecological design using aggregated provincial data precludes causal inference and may be subject to ecological fallacy, whereby associations observed at the population level do not necessarily reflect individual-level relationships. Second, the cross-sectional nature of the correlation analysis cannot establish temporal relationships or rule out reverse causation, particularly for the health post indicators. Third, the study relies on administrative data which may be subject to reporting biases, variations in surveillance quality, and measurement error across provinces (Durrheim et al., 2021). Fourth, the analysis does not account for potential confounding variables such as population density, urbanization, socioeconomic status, migration patterns, or historical outbreak patterns that may influence both the independent variables and the incidence of measles.

CONCLUSION

This study demonstrates strong negative correlations between immunization coverage, health facility access, vitamin A supplementation, breastfeeding practices, and the incidence of measles across Indonesian provinces. The findings reinforce the central importance of achieving and maintaining high two-dose measles vaccination coverage as the cornerstone of measles elimination efforts. Complementary interventions including improved health system access, vitamin A supplementation, and promotion of optimal breastfeeding practices appear to contribute to measles control, though the mechanisms and causal pathways require further investigation. The non-significant findings for integrated health post training and activation highlight the complexity of evaluating programmatic interventions using cross-sectional ecological data and underscore the need for longitudinal evaluations that can account for temporal relationships and reverse causation. To achieve measles elimination, Indonesia must implement comprehensive strategies that combine sustained high vaccination coverage, equitable access to quality health services, targeted catch-up campaigns for underserved populations, and robust surveillance systems to detect and respond rapidly to outbreaks.

REFERENCES

Adjei, M. R., Longsignikuu, A., Iddris, I. S., Abdulai, M. A., Musah, Y., Seidu, I., Sulemana, A., & Kenu, E. (2024). Trend of measles-rubella vaccination coverage and impact on measles epidemiology in the Savannah Region, Ghana; 2018-2022: A secondary data analysis. *Vaccine,* 42(6), 1326–1333. https://doi.org/10.1016/j.vaccine.2024.02.024

Antona, D., Levy-Bruhl, D., Baudon, C., Freymuth, F., Lamy, M., Maine, C., Floret, D., & Parent du Chatelet, I. (2025). Investigation of a measles outbreak in a highly vaccinated middle school, France, 2023. *Eurosurveillance,* 30(46), Article

2500130. https://doi.org/10.2807/1560-7917.ES.2025.30.46.2500130

Arsenault, C., Jordan, K., Lee, D., Dinsa, G., Manzi, F., Marchant, T., & Kruk, M. E. (2018). Equity in antenatal care quality: An analysis of 91 national household surveys. *The Lancet Global Health,* 6(11), e1186–e1195. https://doi.org/10.1016/S2214-109X(18)30389-9

Bernal, J. L., Cummins, S., & Gasparrini, A. (2017). Interrupted time series regression for the evaluation of public health interventions: A tutorial. *International Journal of Epidemiology,* 46(1), 348–355. https://doi.org/10.1093/ije/dyw098

Chacko, S., Kamal, M., Hastuti, E. B., Mildya, F., & Kelyombar, C. (2023). Progress toward measles and rubella elimination Indonesia, 2013–2022. *Morbidity and Mortality Weekly Report,* 72(42), 1143–1148. https://doi.org/10.15585/mmwr.mm7242a2

Comfort, H., Lafta, R. K., Flaxman, A. D., Al-Waily, A., & Hagopian, A. (2022). Association between subnational vaccine coverage, migration, and incident cases of measles, mumps, and rubella in Iraq, 2001–2016. *Frontiers in Public Health*, 9, Article 689458. https://doi.org/10.3389/fpubh.2021.689458

Durrheim, D. N., Andrus, J. K., Tabassum, S., Bashour, H., Githanga, D., & Pfaff, G. (2021). A dangerous measles future looms beyond the COVID-19 pandemic. *Nature Medicine,* 27(3), 360–361. https://doi.org/10.1038/s41591-021-01237-5

Fahriani, M., Anwar, S., Yufika, A., Bakhtiar, B., Wardani, E., Winardi, W., Arisanti, N., Mahdi, I. A., Burhan, E., Imrie, A., Groneberg, D. A., Kuch, U., Muller, R., Wagner, A. L., & Harapan, H. (2025). Developing community-based surveillance systems for vaccine-preventable diseases: Lessons learned from Indonesia. *Global Health Action,* 18(1), Article 2548083. https://doi.org/10.1080/16549716.2025.2548083

Gavi, the Vaccine Alliance. (2020). *School-based immunisation: Lessons learned and best practices.* Gavi.

Hanson, L. A., Korotkova, M., Lundin, S., Håversen, L., Silfverdal, S. A., Mattsby-Baltzer, I., Strandvik, B., & Telemo, E. (2003). The transfer of immunity from mother to child. *Annals of the New York Academy of Sciences*, 987, 199–206. https://doi.org/10.1111/j.1749-6632.2003.tb06049.x

Imdad, A., Mayo-Wilson, E., Herzer, K., & Bhutta, Z. A. (2017). Vitamin A supplementation for preventing morbidity and mortality in children from six months to five years of age. C*ochrane Database of Systematic Reviews,* 3(3), Article CD008524. https://doi.org/10.1002/14651858.CD008524.pub3

Imdad, A., Mayo-Wilson, E., Herzer, K., & Bhutta, Z. A. (2022). Vitamin A supplementation for preventing morbidity and mortality in children from six months to five years of age. *Cochrane Database of Systematic Reviews*, 2022(3), Article CD008524. https://doi.org/10.1002/14651858.CD008524.pub4

Minta, A. A., Ferrari, M., Antoni, S., Lambert, B., Sayi, I., Mamou, M. B., Diallo, M. S., Oteri, A., Hatcher, C., Patel, M. K., & O'Connor, P. (2024). Progress toward measles elimination—Worldwide, 2000–2023. *Morbidity and Mortality Weekly Report,* 73(45), 1036–1042. https://doi.org/10.15585/mmwr.mm7345a4

Ministry of Health of Indonesia. (2025). KLB Campak Meningkat, Kemenkes Ingatkan Pentingnya Imunisasi Lengkap. *KLB Campak Meningkat, Kemenkes Ingatkan Pentingnya Imunisasi Lengkap*

Moraga-Llop, F., Fernández-Prada, M., Grande-Tejada, A. M., Martínez-Alcorta, L. I., Moreno-Pérez, D., & Oltra Benavent, M. (2021). Recovering the delay in the vaccination schedule due to COVID-19 pandemic. *Vacunas*, 22(3), 129–135. https://doi.org/10.1016/j.vacun.2021.04.001

Morgenstern, H. (1995). Ecologic studies in epidemiology: Concepts, principles, and methods. *Annual Review of Public Health,* 16, 61–81. https://doi.org/10.1146/annurev.pu.16.050195.000425

Moss, W. J. (2017). Measles. *The Lancet,* 390(10111), 2490–2502. https://doi.org/10.1016/S0140-6736(17)31463-0

Noori, N., Rohani, P., & Metcalf, C. J. E. (2022). Potential impacts of mass nutritional supplementation on measles dynamics: A simulation study. *American Journal of Tropical Medicine and Hygiene*, 107(4), 863–872. https://doi.org/10.4269/ajtmh.21-1083

Nurlatifah, T., Barlianto, W., Wiyasa, W. A., Kusuma, C., Sari, T. L., & Bachtiar, N. S. (2021). Determination factors associated with immune responses towards first dose Edmonston-Zagreb (EZ) measles vaccine in Indonesian infants. *Medical Archives*, 75(5), 335–339. https://doi.org/10.5455/MEDARH.2021.75.335-339

Oteri, A. J., Ayobami, O., Umeh, G., Balogun, M., Biya, O., Shuaib, F., Mkanda, P., Nsubuga, P., Nguku, P., Banda, R., & Etsano, A.

(2023). Nigeria's journey to integration of injectable antigens in mass vaccination campaign: Benefits and challenges using the 2019 meningitis A and measles integrated campaign. *Journal of Community Medicine and Public Health,* 7(4), Article 392. https://doi.org/10.29011/2577-2228.100392

Panda, B. K., Mishra, S. K., & Awofeso, N. (2020). Socio-demographic correlates of first dose of measles (MCV1) vaccination coverage in India. *BMC Public Health,* 20(1), Article 1378. https://doi.org/10.1186/s12889-020-09321-0

Pangaribuan, L., Tjitra, E., Saputra, W., Laksono, A. D., & Mahmud, A. (2020). The performance of integrated health posts (Posyandu) for early detection and prevention of malnutrition in Indonesia. *Journal of Public Health Research,* 9(3), Article 1819. https://doi.org/10.4081/jphr.2020.1819

Patel, M. K., Goodson, J. L., Alexander, J. P., Kretsinger, K., Sodha, S. V., Steulet, C., Gacic-Dobo, M., Rota, P. A., McFarland, J., Menning, L., Mulders, M. N., & Crowcroft, N. S. (2021). Progress toward regional measles elimination — Worldwide, 2000–2020. *Morbidity and Mortality Weekly Report,* 70(45), 1563–1569. https://doi.org/10.15585/mmwr.mm7045a1

Rachlin, A., Danovaro-Holliday, M. C., Diallo, M. S., Stenger, R., Sugerman, D., Wallace, A. S., & Sodha, S. V. (2024). Building data triangulation capacity for routine immunization and vaccine preventable disease surveillance programs to identify immunization coverage inequities. *Vaccines,* 12(6), Article 646. https://doi.org/10.3390/vaccines12060646

Ramadhani, F. H., Azizah, R., Jalaludin, J., & Kurniawidjaja, L. M. (2023). Meta-analysis and systematic review: Risk factors of measles incidence in Indonesia (2012–2021). *Jurnal Kesehatan Masyarakat,* 19(1), 135–144. https://doi.org/10.15294/kemas.v19i1.43060

Razali, N. M., & Wah, Y. B. (2011). Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. *Journal of Statistical Modeling and Analytics,* 2(1), 21-33.

Sari, R., & Astutik, E. (2024). Korelasi cakupan imunisasi MR dan suplementasi vitamin A terhadap kejadian campak di Jawa Timur. *Jurnal Analisis Jawa,* 3(1), 1–12. https://doi.org/10.29241/jaj.v3i1.1942

Sato, R., Makinde, O. A., Daam, K. C., Olawepo, J. O., Yusuf, K. M., Ismail, T. S., Ota, M., & Gilmour, S. (2022). Geographical and time trends of measles incidence and measles vaccination coverage and their correlation in Nigeria. *Human Vaccines & Immunotherapeutics,* 18(5), Article 2114697. https://doi.org/10.1080/21645515.2022.2114697

Shariff, S., Itani, R., Oseili, T., Wellington, J., & Nazir, A. (2023). The measles outbreak in Indonesia: An assessment of the 2023 epidemic. *International Journal of Surgery: Global Health, 6*(5), Article e161. https://doi.org/10.1097/gh9.0000000000000161

Shet, A., Carr, K., Danovaro-Holliday, M. C., Sodha, S. V., Prosperi, C., Wunderlich, J., Wonodi, C., Reynolds, H. W., Mirza, I., Gacic-Dobo, M., O'Brien, K. L., & Lindstrand, A. (2022). Impact of the SARS-CoV-2 pandemic on routine immunisation services: Evidence of disruption and recovery from 170 countries and territories. *The Lancet Global Health,* 10(2), e186–e194. https://doi.org/10.1016/S2214-109X(21)00512-X

Sethi, Y., Vora, V., Agarwal, P., Murli, H., Padda, I., & Emran, T. B. (2023). Recent measles outbreaks in Maharashtra, India and the role of COVID-19: Lessons learned from a lower middle-income country. International *Journal of Surgery: Global Health*, 6(5), Article e278. https://doi.org/10.1097/gh9.0000000000000278

Smith, E. R., Hurt, L., Chowdhury, R., Sinha, B., Fawzi, W., Edmond, K. M., & Neovita Study Group. (2017). Delayed breastfeeding initiation and infant survival: A systematic review and meta-analysis. *PLoS ONE*, 12(7), Article e0180722. https://doi.org/10.1371/journal.pone.0180722

Thakur, C., Gupta, N., Pokhrel, N., Adhikari, S., & Dhimal, M. (2024). Stumbling blocks on the path to measles-free Nepal: Impact of the COVID-19 pandemic. *Tropical Medicine and Health,* 52(1), Article 7. https://doi.org/10.1186/s41182-024-00576-6

UNICEF Indonesia. (2022). *Indonesia's Catch-Up Immunization Campaign Tackles Major Decline in Childhood Immunization.* https://www.unicef.org/indonesia/press-releases/indonesias-catch-immunization-campaign-tackles-major-decline-childhood-immunization

UNICEF Indonesia. (2023). *Indonesia Targets Low Vaccination Areas to Tackle Decline in Childhood Immunization.* https://www.unicef.org/indonesia/press-releases/indonesia-targets-low-vaccination-areas-tackle-decline-childhood-immunization

Utazi, C. E., Thorley, J., Alegana, V. A., Ferrari, M. J., Takahashi, S., Metcalf, C. J. E., Lessler, J., & Tatem, A. J. (2019). Mapping vaccination coverage to explore the effects of delivery mechanisms and inform vaccination strategies. *Nature Communications,* 10(1), Article 1633. https://doi.org/10.1038/s41467-019-09611-1

Verguet, S., Johri, M., Morris, S. K., Gauvreau, C. L., Jha, P., & Jit, M. (2015). Controlling measles using supplemental immunization activities: A mathematical model to inform optimal policy. *Vaccine,* 33(10), 1291–1296. https://doi.org/10.1016/j.vaccine.2014.11.050

Victora, C. G., Bahl, R., Barros, A. J. D., França, G. V. A., Horton, S., Krasevec, J., Murch, S., Sankar, M. J., Walker, N., Rollins, N. C., & The Lancet Breastfeeding Series Group. (2016). Breastfeeding in the 21st century: Epidemiology, mechanisms, and lifelong effect. *The Lancet,* 387(10017), 475–490. https://doi.org/10.1016/S0140-6736(15)01024-7

Wang, R., Jing, W., Li, M., Xin, Y., Liu, Y., & Liu, M. (2022). Trends of the global, regional, and national incidence of measles, vaccine coverage, and risk factors in 204 countries from 1990 to 2019. *Frontiers in Medicine,* 8, Article 798031. https://doi.org/10.3389/fmed.2021.798031

World Health Organization. (2011). *Vitamin A supplementation in infants and children 6–59 months of age.* World Health Organization.

World Health Organization. (2017). Measles vaccines: WHO position paper – April 2017. *Weekly Epidemiological Record,* 92(17), 205–228.

World Health Organization. (2020). Measles and rubella strategic framework: 2021-2030. *In World Health Organization.* https://www.who.int/publications/i/item/measles-and-rubella-strategic-framework-2021-2030

World Health Organization. (2021). *Measles outbreaks Strategic Response Plan 2021-2023.* https://apps.who.int/iris/bitstream/handle/10665/340657/9789240018600-eng.pdf

World Health Organization. (2025). Measles Cases Surge Worldwide, Infecting 10.3 Million People in 2023. *Neurosciences* (Riyadh, Saudi Arabia), 30(1), 73–74. https://www.who.int/news/item/14-11-2024-measles-cases-surge-worldwide--infecting-10.3-million-people-in-2023

Zaini, N., Idris, I. B., & Ahmad, N. (2023). Resurgence of measles infection among children: Findings from a surveillance-based population study. *Paediatrica Indonesiana*, 63(3), 162–168. https://doi.org/10.14238/pi63.3.2023.162-8