Jurnal Epidemiologi Kesehatan Komunitas
11 (4), 2026, 415-424

JEKK



Spatial Mapping and Analysis of Complete Basic Immunization, DPT-HB-Hib Immunization, Nutritional Status, Exclusive Breastfeeding and Diphtheria in East Java, 2025

Firman Suryadi Rahman[1*], Safira Aurellia Salsabila[2], Khusnul Fitri Hamidah[3], Fitriah Fitriah[4]

[1]Department of Epidemiology, Biostatistic, Population Studies and Health Promotion, Faculty of Public Health, Universitas Airlangga
[2]Department of Epidemiology, Biostatistic, Population Studies and Health Promotion, Faculty of Public Health, Universitas Airlangga
[3]School of Medicine and Dentistry, Griffith University, Gold Coast, QLD Australia
[4]Division of Surveillance and Immunization, Surabaya Health Office, Surabaya, Indonesia

Article Information : Received 04 September 2026 ; Last Revised 18 October 2026 ; Accepted 21 August 2026 ; Available Online 12 November 2026 ; Published 15 November 2026

ABSTRACT

Background: The Diphtheria-Pertussis-Tetanus (DPT) immunization program has been part of Indonesia's national immunization program since 1976. Nevertheless, diphtheria remains a public health problem, as evidenced by the continued occurrence of cases and deaths each year. In 2025, the number of cases in East Java rose again to 363, with 8 deaths (CFR of 2.2%), spread across 37 of the province's 38 districts and cities. This study aims to map and analyze the relationship between Complete Basic Immunization (CBI), DPT-HB-Hib immunization, nutritional status, and exclusive breastfeeding with diphtheria cases in East Java Province in 2025.
Methods: This is an analytical observational study with an ecological design using secondary data from the 2025 East Java Provincial Health Profile. Analysis was conducted by mapping using QGIS, as well as bivariate analysis using Spearman's correlation test.
Result: In 2025, immunization coverage in East Java Province was 84.8% for CBI, 81.8% for DPT-HB-Hib dose 1, 81.4% for DPT-HB-Hib dose 3, and 82.7% for DPT-HB-Hib dose 4, all below the 95% target. The results showed an association between CBI (ρ=0.652; p<0.001), DPT-HB-Hib dose 1 (ρ=0.649; p<0.001), DPT-HB-Hib dose 3 (ρ=0.650; p<0.001), DPT-HB-Hib dose 4 (ρ=0.689; p<0.001), moderate wasting toddlers (ρ=0.437; p=0.006), and exclusive breastfeeding (ρ=0.595; p<0.001). Meanwhile, severe wasting toddlers did not show a significant association (ρ=0.215; p=0.195).
Conclusion: Therefore, efforts to increase immunization coverage, improve nutritional status, and promote exclusive breastfeeding need to be continuously optimized.

Keywords: Complete basic immunization ; Diptheria ; Exclusive breastfeeding ; Nutritional status ; Spatial

Copyright © 2026 by Jurnal Epidemiologi Kesehatan Komunitas. This is an open-access article under the CC BY-SA License (https://creativecommons.org/licenses/by-sa/4.0)
DOI : https://doi.org/10.14710/jekk.v11i4.34473

*Corresponding author, firmansrahman@fkm.unair.ac.id

Introduction

Diphtheria is an acute infectious disease caused by the bacterium *Corynebacterium diphtheriae* and is one of the diseases that can be prevented through immunization (PD3I). Although the Diphtheria-Pertussis-Tetanus (DPT) Immunization Program has been in place since 1976, cases and deaths from diphtheria continue to be reported to this day.[13] Data from the World Health Organization (WHO) show that the global trend in diphtheria cases has increased approximately 3.5-fold over the past five years, from 8,659 cases in 2021 to 30,206 cases in 2025. The Southeast Asia region has been the second-largest contributor to global diphtheria incidence since 2021, following Africa.[21] Although reported diphtheria cases in 2025 have decreased compared to the previous year, the disease remains widespread across various parts of the world and continues to be endemic in many developing countries, including Indonesia.

In line with the global situation, diphtheria also remains a public health issue in Indonesia. In 2024, Indonesia reported 943 cases of diphtheria spread across 33 provinces, with 42 deaths and a Case Fatality Rate (CFR) of 4,5%. Although the national case count has slightly decreased compared to 2023, East Java Province remains the province with the highest number of diphtheria cases in Indonesia, totaling 339 cases with 6 deaths (CFR 1,8%). In 2025, the number of cases in East Java rose again to 363 cases with 8 deaths (CFR 2,2%), spread across 37 of 38 regencies and cities.

Immunization is the primary preventive measure against diphtheria through the development of specific immunity. Under the National Immunization Program, protection against diphtheria is provided through the Complete Basic Immunization (CBI), which includes three doses of the DPT-HB-Hib vaccine, followed by one booster dose.[9,10] Research shows that administration of at least three doses of a vaccine containing the diphtheria component provides 87% effectiveness against symptomatic disease. Vaccine effectiveness increases with the completeness of immunization doses, and a complete history of diphtheria immunization is more effective in reducing the risk of disease severity, complications, and death compared to incomplete immunization.[20] However, CBI coverage in East Java Province in 2025 reached only 84,76%, which is lower than the minimum target of 95% and represents a decline from the 2024 coverage rate of 92,17%. DPT-HB-Hib immunization coverage is also not yet optimal, standing at 81,8% for the first dose, 81,4% for the third dose, and 82,7% for the fourth dose. This situation indicates that there are still groups of children who have not received complete immunization protection, potentially increasing their vulnerability to diphtheria cases.

In addition to immunization, nutritional status and exclusive breastfeeding are also believed to play a role in children's susceptibility to diphtheria infection. Poor nutritional status can impair immune system function and increase children's susceptibility to infectious diseases.[14] A study in East Java showed that poor nutritional status is associated with diphtheria cases, although this association was not consistently found in 2020 and 2021.[19] Meanwhile, breast milk contains various immunological and bioactive components that help support the immune system and provide protection against infections in infants.[1] By 2025, the prevalence of moderate wasting and severe wasting toddlers in East Java Province is projected to be 4,8% and 0,4%, respectively while the rate of exclusive breastfeeding is expected to reach 82,0%. Although the prevalence of moderate wasting and severe wasting has generally been at a relatively low level and exclusive breastfeeding coverage has increased compared to the previous year, there are still groups of children experiencing nutritional problems or who have not received exclusive breastfeeding. Epidemiological evidence regarding the relationship between nutritional status and exclusive breastfeeding and the incidence of diphtheria remains limited, and available research findings have not yet shown consistent results

Based on the above discussion, the high number of diphtheria cases in East Java Province and the uneven immunization coverage indicate that diphtheria remains a

Copyright ©2026 JEKK, ISSN 2614-4854

public health issue requiring attention. Furthermore, research findings on the relationship between nutritional status and exclusive breastfeeding and the incidence of diphtheria remain limited. These conditions highlight the need for further research to identify factors associated with diphtheria incidence at the regional level. Therefore, this study aims to map the distribution of diphtheria cases along with their risk factors and to analyze the association between CBI, DPT-HB-Hib immunization, the nutritional status of toddlers, and exclusive breastfeeding with diphtheria cases in East Java Province in 2025.

Methods

This study is an analytical observational study with an ecological study design. It uses secondary data sourced from the 2025 East Java Provincial Health Profile, with the 38 regencies and cities in East Java Province serving as the units of analysis. The study aims to describe the distribution of diphtheria cases based on risk factors, including CBI, DPT-HB-Hib doses 1, 3, and 4, the nutritional status of toddlers (moderate wasting and severe wasting), and exclusive breastfeeding. All variables were obtained from the East Java Provincial Health Profile. Diphtheria cases were the number of cases of all age groups reported in each regency. CBI and DPT-HB-Hib doses 1, 3, and 4 were the immunization coverage of each regency/city as reported in the Health Profile. Moderate wasting were those with a weight-for-height z-score of −3 SD to <−2 SD, and severe wasting were those with a z-score of <−3 SD. Exclusive breastfeeding was the provision of breast milk only to infants from birth up to 6 months of age, without any additional food or drink.

Descriptive spatial mapping was performed using *Quantum Geographic Information System* (QGIS) version 3.44.1. Diphtheria incidence per 100,000 population was calculated using the total population as the denominator, as cases are reported for all ages and age-specific population data were unavailable. For immunization coverage, choropleth maps used two categories, <95% and ≥95%, based on the coverage threshold commonly required to achieve herd immunity against diphtheria. For the other indicators, choropleth maps used four-class quantile classification because no standardized cut-offs exist for these indicators at the regency/city level. Map colours for the quantile-based indicators therefore represent relative categories, not epidemiologically defined risk thresholds. No spatial statistical analysis was performed.

Analyses were conducted in R. As the Shapiro-Wilk test showed non-normal distributions (*p-value*<0,05), Spearman's rank correlation was used (α = 0,05). Unlike the mapping, the correlation analysis used absolute numbers of diphtheria cases and of each risk factor, which are influenced by population size and may yield positive correlations even for protective factors. Results are therefore interpreted as area-level associations, not causal or individual-level effects.

Result

A. Spatial Distribution of Diphtheria Cases in East Java Province in 2025

Diphtheria cases in East Java Province in 2025 were distributed across nearly all regencies and cities, with varying incidence rates. Based on Figure 1, areas with higher diphtheria incidence tend to be concentrated in the central part of East Java Province and on Madura Island, while some areas in the east and south show lower incidence. The highest incidence was found in Bangkalan Regency (6,2 per 100,000 population), followed by Mojokerto (3,6 per 100,000 population) and Batu (3,1 per 100,000 population)

Copyright ©2026 JEKK, ISSN 2614-4854



Figure 1. Map of Diphtheria Case Incidence Distribution in East Java Province in 2025 (Source: Profil Kesehatan Provinsi Jawa Timur, 2026)

B. Spatial Distribution of Complete Basic Immunization Coverage in East Java Province in 2025

Based on Figure 2, the coverage of CBI in East Java Province shows that most regencies and cities have not reached the 95% target. Only a few areas, mainly in and around the Surabaya metropolitan region and several northern parts of the province, achieved coverage above 95%.

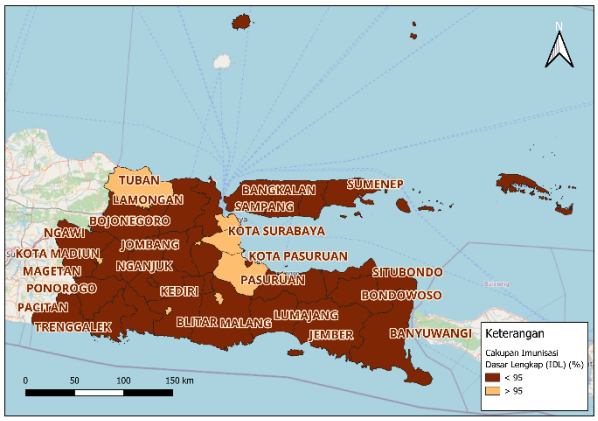


Figure 2. Map of the Distribution of Complete Basic Immunization (CBI) Coverage in East Java Province in 2025 (Source: Profil Kesehatan Provinsi Jawa Timur, 2026)

C. Spatial Distribution of DPT-HB-Hib Immunization Coverage in East Java Province in 2025

Based on Figures 3 through 5, DPT-HB-Hib immunization coverage for doses 1, 3, and 4 in East Java Province in 2025 varied across districts and cities. For all three doses, most areas remained below the 95% target, while the areas that achieved it were limited and concentrated in and around Surabaya City. The three maps show relatively similar spatial patterns, particularly in the areas with the highest coverage. However, there are slight differences in the number and location of areas reaching the target between doses. For dose 4, the number of areas that met the target appears to be more scattered, including a few areas in the northern part of the province.



Figure 3. Map of DPT-HB-Hib Dose 1 Immunization Coverage in East Java Province in 2025 (Source: Profil Kesehatan Provinsi Jawa Timur, 2026)

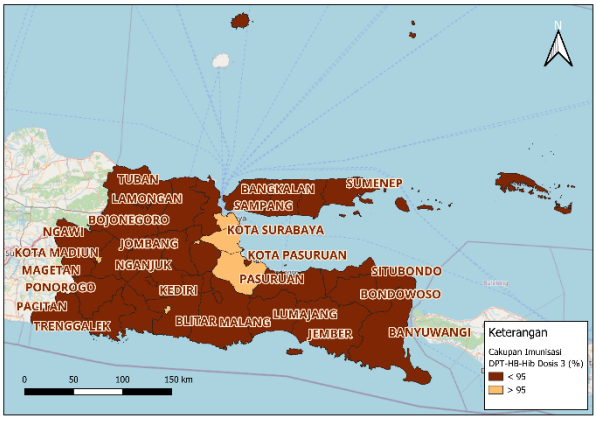


Figure 4. Map of DPT-HB-Hib Dose 3 Immunization Coverage in East Java Province in 2025 (Source: Profil Kesehatan Provinsi Jawa Timur, 2026)

Copyright ©2026 JEKK, ISSN 2614-4854



Figure 5. Map of DPT-HB-Hib Dose 4 Immunization Coverage in East Java Province in 2025 (Source: Profil Kesehatan Provinsi Jawa Timur, 2026)

D. Spatial Distribution of Undernourished and Severely Undernourished Toddlers in East Java Province in 2025

Based on Figure 6, the percentage of undernourished toddlers in East Java Province in 2025 varies across districts and cities. The areas with the highest percentage of undernourished toddlers are Pasuruan City, Pacitan District, Pasuruan District, Ngawi District, and Tuban District, with percentages ranging from 5,5% to 13,9%, while the areas with the lowest percentages are in Banyuwangi Regency, Surabaya City, Sampang Regency, Sidoarjo Regency, and Pamekasan Regency, with percentages ranging from 1,8–3,5%.

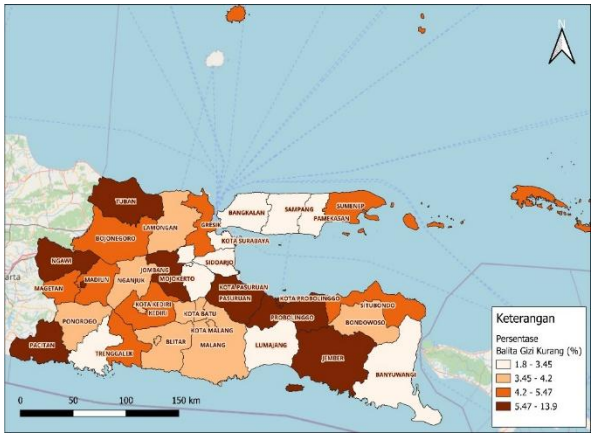


Figure 6. Map of the Distribution of the Percentage of Undernourished Toddlers in East Java Province in 2025 (Source: Profil Kesehatan Provinsi Jawa Timur, 2026)

Based on Figure 7, the percentage of severely malnourished toddlers in East Java Province in 2025 varies across regencies and cities. The map shows that the percentages of undernourished and malnourished infants are unevenly distributed across all regencies and cities in East Java Province, with some areas having higher percentages than others.

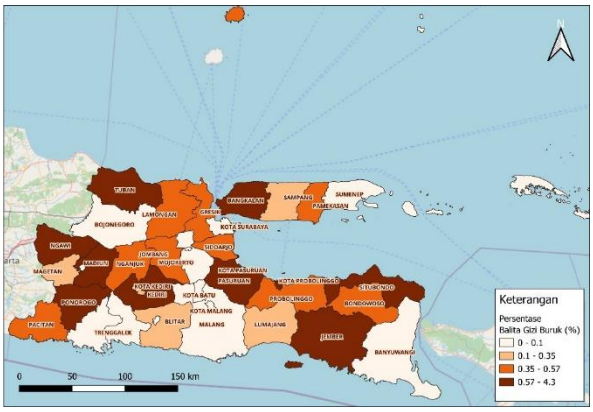


Figure 7. Map of the Distribution of the Percentage of Undernourished Toddlers in East Java Province in 2025 (Source: Profil Kesehatan Provinsi Jawa Timur, 2026)

E. Spatial Distribution of Exclusive Breastfeeding Coverage in East Java Province in 2025

Based on Figure 8, the coverage of exclusive breastfeeding in East Java Province in 2025 shows variation across regencies and cities. The areas with the highest exclusive breastfeeding coverage are Bojonegoro Regency, Sidoarjo Regency, Mojokerto Regency, Gresik Regency, and Banyuwangi Regency, while the areas with the lowest coverage are Pasuruan City, Probolinggo Regency, Tulungagung Regency, Batu City, and Sumenep Regency.

F. Correlation Analysis of Diphteria Cases and Associated Factors

The *Spearman* correlation test in table 1 indicates that CBI, DPT-HB-Hib immunization doses 1, 3, and 4, undernourished toddlers, and exclusive breastfeeding have a significant association with diphtheria cases in East Java Province in 2025 (*p-value*<0,05), with DPT-HB-Hib dose 4 showing the highest correlation coefficient, followed by CBI, DPT-HB-Hib doses 3, DPT-HB-Hib dose 1, exclusive breastfeeding, and moderate wasting toddlers. Meanwhile, severe wasting toddlers showed no significant

Copyright ©2026 JEKK, ISSN 2614-4854

association with diphtheria cases, with a weak correlation coefficient.

Table 1. Results of the Correlation Test for CBI, DPT-HB-Hib Immunization, Nutritional Status, and Exclusive Breastfeeding with Diphtheria Cases in East Java Province in 2025

Variable	ρ	*p-value*	Correla-tion Level
Complete Basic Immunization (CBI)	0,652	<0,001	Strong
DPT-HB-Hib Dose 1	0,649	<0,001	Strong
DPT-HB-Hib Dose 3	0,650	<0,001	Strong
DPT-HB-Hib Dose 4	0,689	<0,001	Strong
Moderate Wasting Toddlers	0,437	0,006	Moderate
Severe Wasting Toddlers	0,215	0,195	Weak
Exclusive Breastfeeding	0,595	<0,001	Moderate

Discussion

A. The Relationship Between Complete Basic Immunization (CBI) and Diphtheria Cases in East Java Province in 2025

The CBI coverage in East Java Province in 2025 still shows significant disparities across regions, ranging from 64,7% to 112,1%. The CBI coverage in East Java Province in 2025 still shows significant disparities across regions, ranging from 64,7% to 112,1%. Coverage exceeding 100% was reported in the Health Profile and may reflect a mismatch between the numerator (children immunized) and the denominator (target population estimated from population projections), such as immunization of children from neighboring areas or underestimation of the target population. These values were used as reported, and should be interpreted with caution.

Most districts and cities have not yet reached the 95% *herd immunity* threshold. CBI is a series of mandatory immunizations administered to infants before the age of one year, consisting of 1 dose of Hepatitis B, 1 dose of BCG, 3 doses of DPT-HB-Hib, 4 doses of oral polio, and 1 dose of measles-rubella.[9,10] Administration of the three primary doses of the DPT-HB-Hib vaccine is necessary to establish immunity, including against diphtheria.[12] When immunization coverage is high and evenly distributed within a population, the chain of transmission is broken because the majority of individuals are immune, thereby providing indirect protection to those who have not been or cannot be vaccinated.[15] Conversely, low immunization coverage can result in a remaining proportion of susceptible individuals in the population.[6]

The results of the study indicate that there is a positive correlation between CBI and diphtheria cases in East Java Province in 2025, with a strong level of correlation strength (*ρ-value*=0,652; *p-value*<0,001). This finding should not be interpreted as evidence that higher immunization coverage increases diphtheria occurrence, and it appears to contradict the inverse relationship expected from herd immunity theory. A similar positive relationship was also reported in Surabaya (r = 0,471; *p-value*= 0,007)[17], suggesting that such patterns may stem from factors other than a true effect of immunization. First, because absolute case numbers were used, regencies/cities with larger populations naturally recorded more cases as well as more immunized children. Second, differences in surveillance and case-detection intensity may have led to more cases being recorded in some areas. Third, immunization coverage may not temporally correspond to disease occurrence, and outbreak-affected areas may have intensified immunization reactively after cases emerged. Residual ecological confounding

Copyright ©2026 JEKK, ISSN 2614-4854

may also have contributed. Finally, as the data were aggregated at the regency/city level, these findings are subject to the ecological fallacy, as area-level associations cannot be assumed to apply to individuals. Direct causal interpretation is therefore not warranted.

B. The Relationship Between DPT-HB-Hib Immunization and Diphtheria Cases in East Java Province in 2025

DPT-HB-Hib is a combination vaccine that provides specific protection against diphtheria, pertussis, tetanus, hepatitis B, and *Haemophilus influenzae* type b. In the prevention of diphtheria, the *diphtheria toxoid* component of the vaccine plays a role in providing approximately 87% protection against symptomatic diphtheria after administration of three or more doses.[20] In Indonesia, diphtheria prevention efforts are carried out through the administration of the pentavalent DPT-HB-Hib vaccine, which is given in three primary doses starting at 2 months of age with one-month intervals, followed by a *booster* dose for toddlers and elementary school children to maintain immunity against diphtheria.[9,10] Booster doses are necessary because antibody levels can decline over time following primary immunization; therefore, follow-up immunization is essential to restore protective antibody levels and maintain immunity against diphtheria.[12]

The results of this study show a strong and consistent correlation coefficient between DPT-HB-Hib dose 1 (*ρ-value*=0,649; *p-value*<0,001), DPT-HB-Hib dose 3 (*ρ-value*=0,650; *p-value*<0,001), and dose 4/booster (*ρ-value*=0,689; *p-value*<0,001) and cases of diphtheria in East Java Province in 2025. These positive correlations should not be interpreted as evidence that higher DPT-HB-Hib coverage increases diphtheria occurrence, and they are contrary to the inverse relationship expected from immunization. A positive correlation was also reported across 38 regencies/cities in East Java in 2019 for dose 3 (r = 0,53; *p-value*=0,01)[2], whereas a negative correlation was found elsewhere (r = −0,191; *p-value*=0,011).[22] As discussed for CBI, the positive direction in this study is most likely influenced by population size, differences in surveillance intensity, temporal mismatch, reactive immunization, and residual ecological confounding. The slightly higher coefficients from dose 1 to dose 4 should likewise not be interpreted as evidence of greater protective immunity, as this analysis was ecological and cannot assess individual-level vaccine effectiveness.

C. The Relationship Between Toddler Nutritional Status (Moderate Wasting and Severe Wasting) and Diphtheria Cases in East Java Province in 2025

Nutritional status is closely related to the body's ability to fight infections, including infections caused by *Corynebacterium diphtheriae*. Children with poor or undernourished nutritional status are at higher risk of developing infectious diseases.[16] Biologically, poor nutritional status can increase the risk of diphtheria because it leads to a decline in immune system function, including antibody production and the activity of immune cells, making individuals more susceptible to both bacterial and viral infections.[7] The relationship between nutritional status and infection is bidirectional. Malnutrition can lower the body's resistance to infection, while the infection itself can worsen a child's nutritional status by reducing appetite and impairing nutrient absorption (Bili *et al.,* 2020).

In this study, the number of moderate wasting toddlers showed a statistically significant moderate positive correlation with diphtheria cases in East Java Province in 2025 (*ρ-value*=0,437; *p-value*=0,006), whereas no statistically significant correlation was observed for severe wasting (*ρ-value*=0,215; *p-value*=0,195). The finding for moderate wasting is consistent with a previous study in East Java, which reported a positive correlation with diphtheria incidence in 2019 (*ρ-value*=0,479; *p-value*=0,002), although no significant correlation was found for 2020 and 2021 (*p-value*>0,05).[19] These differing results suggest that the relationship between nutritional status and diphtheria may vary across periods, possibly due to changes in population characteristics, epidemiological

Copyright ©2026 JEKK, ISSN 2614-4854

conditions, or other factors not analyzed. As these are ecological correlations based on absolute numbers, they indicate area-level associations only and do not establish that undernutrition causes diphtheria in individual children.

D. The Relationship Between Exclusive Breastfeeding and Diphtheria Cases in East Java Province in 2025

Exclusive breastfeeding plays a role in supporting the development of an infant's immune system, thereby helping to maintain optimal nutritional status and enhance resistance to various diseases.[7] Although breast milk does not contain specific antibodies against the diphtheria toxin, colostrum in breast milk is highly beneficial for infants because it contains the immune substance immunoglobulin A (IgA), which protects infants from various infectious diseases, such as diphtheria.[18] However, specific protection against diphtheria still depends on the formation of antitoxin antibodies through immunization containing diphtheria toxoid. The role of breastfeeding is more indirect, achieved through strengthening the immune system and maintaining good nutritional status.

This study found a moderate positive correlation between exclusive breastfeeding and diphtheria cases in East Java Province in 2025 (ρ-*value*=0,595; *p-value*<0,001). This finding should not be interpreted as evidence that exclusive breastfeeding increases diphtheria occurrence. It differs from an individual-level study reporting that exclusive breastfeeding was associated with fewer infectious diseases among toddlers (OR = 0,222; *p-value*<0,001).[8]

Several factors may explain the positive direction observed here. Because absolute numbers were used, regencies/cities with larger populations naturally recorded more cases as well as more exclusively breastfed infants. The exposure and outcome populations also do not correspond, as exclusive breastfeeding coverage refers to infants aged 0-5 months, whereas diphtheria cases were reported for all age groups. In addition, differences in surveillance and case-detection intensity may have led to more cases being recorded in some areas, and residual ecological confounding, such as regional differences in health service access and population density, may have contributed. Finally, regency/city-level coverage does not indicate whether individual infants or diphtheria cases were exclusively breastfed, so it cannot be treated as a proxy for individual protection against diphtheria, and these findings are subject to the ecological fallacy.

This study has several limitations. As an ecological study, it examined associations at the regency/city level, so the findings cannot be applied to individuals and are subject to the ecological fallacy. The correlation analysis also used absolute numbers, which are influenced by population size, whereas the mapping used incidence rates; this may have produced positive correlations even for factors expected to be protective. In addition, incidence was calculated using the total population because age-specific population data were unavailable, which may not reflect the risk in the age groups targeted by immunization and nutrition programs. Because exposure and outcome data came from the same year, temporality could not be established, and the use of secondary data with bivariate analysis limited adjustment for potential confounders. Differences in surveillance and reporting among regencies/cities may also have affected the number of recorded cases. Finally, the spatial component was limited to descriptive mapping, and quantile classes represent relative rather than risk-based categories.

Conclusions

This ecological study found that immunization coverage in East Java Province in 2025 remained suboptimal, as most regencies and cities had not reached the 95% target for CBI and DPT-HB-Hib doses 1, 3, and 4. Positive correlations were found between the number of diphtheria cases and CBI, DPT-HB-Hib immunization, moderate wasting, and exclusive breastfeeding, whereas no significant correlation was observed for severe wasting. The positive direction for the immunization and breastfeeding indicators is

Copyright ©2026 JEKK, ISSN 2614-4854

contrary to theoretical expectations and should not be interpreted as a causal or protective effect. It is more likely influenced by population size, differences in surveillance, and other regional factors, so the findings should be interpreted with caution given the limitations of the ecological design.

Based on these findings, priority should be given to improving immunization coverage in regencies and cities that remain below the 95% target, as low coverage may leave susceptible populations at risk of diphtheria transmission, which is consistent with established evidence although it is not derived from the present correlations. Regencies and cities with a high number of diphtheria cases and a high number of undernourished toddlers may also be prioritized for surveillance and program evaluation. Differences in surveillance and reporting across areas warrant attention, as they may influence the number of recorded cases. Future studies should use incidence rates, age-specific analyses where data allow, individual-level or longitudinal data, and multivariable analysis to clarify these relationships.

Acknowledgement

We would like to express our gratitude to the East Java Provincial Health Office for providing the East Java Provincial Health Profile as the data source for this study. We also extend our appreciation to all parties who provided support and assistance throughout the preparation of this research.

References

1. Alotiby, A. A. 2023. The role of breastfeeding as a protective factor against the development of immune-mediated diseases: A systematic review. *Front. Pediatr.* 11: 1086999.
2. Ashila, N. R. and Hendrati, L. Y. 2023. Risk factors for diphtheria: DPT-HB-Hib 3 immunization and the availability of integrated health centers. *Media Gizi Kesmas* 12, 2: 847-853.
3. Bili, A., Jutomo, L., and Boeky, D. L. 2020. Faktor risiko kejadian gizi kurang pada anak balita di Puskesmas Palla Kabupaten Sumba Barat Daya. *Media Kesehatan Masyarakat* 2, 2: 33-41.
4. Dinas Kesehatan Provinsi Jawa Timur. (2025). *Profil kesehatan Provinsi Jawa Timur tahun 2024*. Dinas Kesehatan Provinsi Jawa Timur. Dinas Kesehatan Provinsi Jawa Timur. (2025). *Profil kesehatan Provinsi Jawa Timur tahun 2024*. Dinas Kesehatan Provinsi Jawa Timur.
5. Dinas Kesehatan Provinsi Jawa Timur. (2026). *Profil kesehatan Provinsi Jawa Timur tahun 2025*. Dinas Kesehatan Provinsi Jawa Timur.
6. Djaafara, B. A., Adrian, V., Eriawati, E., Elyazar, I. R., Hamers, R. L., Baird, J. K., et al. 2026. Modeling the transmission dynamics and control strategies during the 2017 diphtheria outbreak in Jakarta, Indonesia. *Infect. Dis. Model.* 11, 1: 1-15.
7. Kamilla, N. I., Utama, F., and Noviani, N. 2024. Analisis spasial faktor risiko difteri di Provinsi Lampung tahun 2022 dan 2023. *Jurnal Biostatistik, Kependudukan, dan Informatika Kesehatan.* 4, 2: 3-13.
8. Karlinah, N. 2024. Hubungan ASI eksklusif terhadap penyakit infeksi pada balita di Desa Karya Indah. *Jurnal Ilmu Kesehatan Mandira Cendiki.* 3, 7: 18-24.
9. Kementerian Kesehatan Republik Indonesia. 2017. *Pedoman pencegahan dan pengendalian difteri*. https://sehatnegeriku.kemkes.go.id/wp-content/uploads/2018/01/buku-pedoman-pencegahan-dan-penanggulangan-difteri.pdf
10. Kementerian Kesehatan Republik Indonesia. (2017). *Peraturan Menteri Kesehatan Republik Indonesia Nomor 12 Tahun 2017 tentang penyelenggaraan imunisasi* https://peraturan.bpk.go.id/Details/112667/permenkes-no-12-tahun-2017
11. Kementerian Kesehatan Republik Indonesia. (2025). *Profil kesehatan Indonesia tahun 2024*. Kementerian Kesehatan Republik Indonesia

Copyright ©2026 JEKK, ISSN 2614-4854

12. Kitamura, N., Bahkali, K., Quilty, B. J., Edwards, T., Toizumi, M., and Yoshida, L. M. 2022. Waning rate of immunity and duration of protective immunity against diphtheria toxoid as a function of age and number of doses: Systematic review and quantitative data analysis. *Hum. Vaccin. Immunother.* 18, 6: 2099700.
13. Masfufah, S., *et al*. 2023. Hubungan riwayat vaksinasi dan pemberian anti difteri serum (ADS) dengan kejadian kematian kasus difteri di Indonesia.
14. Morales, F., Montserrat-de la Paz, S., Leon, M. J., and Rivero-Pino, F. 2023. Effects of malnutrition on the immune system and infection and the role of nutritional strategies regarding improvements in children's health status: A literature review. *Nutrients* 16, 1: 1. https://doi.org/10.3390/nu16010001
15. Pollard, A. J. and Bijker, E. M. 2021. A guide to vaccinology: From basic principles to new developments. *Nat. Rev. Immunol.* 21, 2: 83-100. https://doi.org/10.1038/s41577-020-00479-7
16. Sari, R. P. and Agustin, K. 2023. Analisis hubungan status gizi dengan kejadian penyakit infeksi pada anak balita di Posyandu wilayah Puskesmas Colomadu I. *Jurnal Ilmu Keperawatan dan Kebidanan.* 14, 1: 171-178.
17. Setiawan, A., Hendrati, L. Y., and Mirasa, Y. A. 2021. The mapping and analysis of diphtheria cases in Surabaya. *Jurnal Biometrika dan Kependudukan.* 10, 1: 45-52.
18. Singarimbun, N. B., Sinaga, S. P., and Pasaribu, S. M. 2023. Perbandingan pertumbuhan bayi dengan pemberian ASI eksklusif dan non-eksklusif. *Journal of Pharmaceutical and Health Research.* 4, 1: 64-68.
19. Suratno, S. A. and Hendrati, L. Y. 2023. Risk factors for diphtheria incidence in East Java: Underweight status, coverage of DPT-HB-Hib3 (2019–2021 period). *Media Gizi Kesmas.* 12, 2: 854-859.
20. Truelove, S. A., Keegan, L. T., Moss, W. J., Chaisson, L. H., Macher, E., Azman, A. S., and Lessler, J. 2020. Clinical and epidemiological aspects of diphtheria: A systematic review and pooled analysis. *Clin. Infect. Dis.* 71, 1: 89-97.
21. World Health Organization. 2026. *Global Immunization Data*. World Health Organization.
22. Wu, Z., Lin, L., Zhang, J., Zhong, J., and Lai, D. 2025. Global burden of diphtheria, 1990-2021: A 204-country analysis of socioeconomic inequality based on SDI and DTP3 vaccination differences before and after the COVID-19 pandemic (GBD 2021). *Front. Public Health* 13: 1597076.

Copyright ©2026 JEKK, ISSN 2614-4854