

## **The Role of Biological and Environmental Factors in Infant Pneumonia: Findings from the 2023 Indonesian Health Survey**

**\*Leka Lutpiatina, Ratih Dewi Dwiyantri, Aima Insana**

Medical Laboratory Technology Poltekkes Kemenkes Banjarmasin, Mistar Cokrokusumo Street 4A Banjarbaru Indonesia. \*Email: leka.zns@gmail.com

**Abstract:** Pneumonia continues to be a leading cause of morbidity and mortality in infants, particularly in developing countries, making risk factor analysis crucial to support evidence-based prevention efforts. This study analyzed factors associated with pneumonia in 28,610 infants aged one year and under using data from the 2023 Indonesian Health Survey to provide a national overview of the distribution of cases and their determinants. This study used a cross-sectional design and analyzed demographic variables, health characteristics, and environmental factors using descriptive analysis, chi-square tests, and odds ratios. The study results showed a pneumonia prevalence of 0.9%, with an increased risk in low birth weight infants (OR 2.425; 95% CI: 1.688–3.483) and infants with a history of diarrhea (OR 2.051; 95% CI: 1.211–3.475), while breastfeeding reduced the risk of pneumonia (OR 0.590; 95% CI: 0.447–0.778). The data also showed greater susceptibility among male infants and those living in urban areas. These findings confirm that pneumonia in infants is influenced by a combination of biological, environmental, and behavioral factors, so public health interventions need to strengthen monitoring of at-risk infants, increase the coverage and quality of breastfeeding, prevent diarrhea, and control exposure to air pollution, especially in urban areas. These findings provide an empirical basis for developing more targeted and effective infant health policies.

**Keywords:** Breastfeeding; diarrhea; health survey; infant pneumonia; low birth weight.

### **INTRODUCTION**

Acute Respiratory Tract Infections (ARI), particularly pneumonia, are a leading cause of morbidity and mortality from infectious diseases worldwide. Nearly four million deaths occur annually from ARI, and approximately 98% of these are from lower respiratory tract infections. The highest mortality burden is found in infants, children, and older people, particularly in low- and middle-income countries<sup>1</sup>.

In Indonesia, research in the eastern region indicates that the risk of ARI increases in children raised by mothers with low levels of knowledge about child care, suboptimal breastfeeding practices, exposure to cigarette smoke, and inadequate housing conditions due to low family income<sup>2</sup>. Similar findings emerged in a study in the slums of Dibrugarh City, which identified the influence of complementary feeding, immunization status, and socioeconomic factors on respiratory disorders in toddlers<sup>3</sup>. Another study by Tazinya A.A. et al. in Cameroon confirmed the association between toddler characteristics, parental characteristics, and breastfeeding patterns with the incidence of ARI<sup>4</sup>.

**Corresponding Author:** Leka Lutpiatina  
Medical Laboratory Technology Poltekkes Kemenkes Banjarmasin.  
Mistar Cokrokusumo Street 4A Banjarbaru Indonesia.  
Email: leka.zns@gmail.com

Research by Lutpiatina et al. (2023) showed that breastfeeding was significantly associated with the incidence of ARI pneumonia in all toddlers ( $p=0.043$ ; OR 1.933) and, specifically, in female toddlers ( $p=0.048$ ; OR 2.652). Toddlers who received formula milk were at higher risk of pneumonia (5). This finding strengthens previous evidence that suboptimal breastfeeding is a risk factor for ARI<sup>2</sup>.

Although the majority of respondents in the study breastfed (81.3%), the small proportion who gave formula milk (18.7%) still showed a strong influence on pneumonia. Low family income also contributed to the decision to breastfeed rather than formula feed<sup>5</sup>. In the final analysis model, Lutpiatina et al. (2024) confirmed that breastfeeding is a predictive indicator of pneumonia in river basins. These results align with a study by Abebaw B. & Damtie D. (2022), which found that partial weaning or mixing breast milk with formula increased the risk of pneumonia more than fivefold (AOR 5.229;  $p=0.001$ )<sup>6</sup>. A similar factor was also revealed by Fasih A. et al. (2021), who found that the shorter the duration of breastfeeding, the higher the risk of pneumonia in toddlers<sup>7</sup>. Children who are not exclusively breastfed are also at risk of developing acute respiratory infections (ARI) (OR 2.18; CI 0.96–4.97)<sup>2</sup>.

Biologically, the benefits of breastfeeding are powerful. Breast milk contains vitamin A, iron, microbiota, and immunological components important for mucosal resistance<sup>8,9</sup>. In addition to nutrition, breastfeeding involves touch and cuddling, which can boost immunity through hormonal mechanisms such as oxytocin, norepinephrine, and endorphins, with a reported greater response in girls<sup>10</sup>. Gender is also associated with early-life health risks. Several studies have shown that baby girls are more likely to be born with low birth weight (LBW). Global studies show a 30% increased risk in baby girls compared to boys<sup>11,12</sup>. Data from Banjar Regency for 2019–2020 consistently show a higher rate of low birth weight among baby girls than among baby boys<sup>13,14</sup>.

LBW is an important determinant of infant mortality and morbidity, as well as long-term health problems<sup>11</sup>. LBW babies require higher nutritional requirements, and breast milk from mothers of premature babies has been shown to have a higher protein content than breast milk from mothers of full-term babies<sup>15,16</sup>. Although formula milk can be nutritionally modified, breast milk still provides a crucial immunological advantage<sup>17</sup>. Studies in India have shown that breastfed low birth weight babies experience fewer serious infections, including pneumonia, than formula-fed babies<sup>18</sup>. These facts support the hypothesis that baby girls—who are more likely to experience low birth weight—gain greater protection from breastfeeding against acute respiratory infections (ARI) and pneumonia.

To date, few national studies have simultaneously analyzed the relationship between breastfeeding, low birth weight (LBW), and pneumonia, while also considering differences in risk based on infant sex. This study offers a novel contribution by integrating these three factors using data from the 2023 Indonesian Health Survey. This study aims to analyze the relationship between breastfeeding, low birth weight (LBW), and pneumonia in infants in Indonesia using 2023 health survey data and to identify risk patterns that may differ by infant sex.

## **MATERIALS AND METHODS**

This study used data from the 2023 Indonesian Health Survey (SKI), a national cross-sectional, observational, non-interventional survey. The 2023 SKI was integrated

with the Basic Health Research (Riskesdas), the Toddler Nutrition Status Survey (SSGI), and the Biomedical and Dental and Oral Examination Survey, producing district/city estimates for Riskesdas and SSGI, as well as national estimates for the biomedical and dental health components. The survey population included all households in Indonesia, with ordinary households serving as the sample units for the Riskesdas, Biomedical and Dental and Oral Examination modules, and toddler households for the SSGI module. Of the 34,500 selected Census Blocks (BS), 34,065 BS (98.74%) were successfully visited across 38 provinces and 514 districts/cities. Data collection was conducted by trained enumerators under the supervision of district and municipal field supervisors, with each team collecting data from 10–12 ordinary households and approximately 7 toddler households. This survey successfully collected data from 315,646 regular households (91.49%) and 284,178 households with children under five (82.37%), encompassing 1,191,692 individuals and 37,443 respondents who underwent biomedical and dental examinations. The 2023 SKI obtained research ethics approval from the relevant ethics committee, and all respondents provided informed consent before data collection.

The analysis included 28,610 infants aged one year and under whose mothers were aged 15–49 years and who gave birth in the five years before the survey and met all study variables. The 2023 SKI questionnaire includes caregiver-reported information regarding a diagnosis of pneumonia made by a healthcare professional in the past 12 months. Responses indicating a diagnosis within  $\leq 1$  month or within the past 1–12 months were categorized as “Yes.” For analysis purposes, “No” and “Don’t know” responses were combined into a single “No” category to allow for binary analysis. Breastfeeding was assessed by whether the infant was still receiving breast milk. Birth weight was categorized as low birth weight ( $< 2500$  grams) and normal birth weight ( $\geq 2500$  grams), and diarrhea history was based on a health worker’s diagnosis within the past month; all “Yes” and “Don’t know” responses were grouped consistently according to analysis requirements. Data collection was conducted by updating household lists, conducting interviews, and measuring and examining as specified in the survey module.

This study uses secondary data from the 2023 SKI. Due to limited data access and software capabilities, the analysis was conducted without applying complex survey weighting. Statistical analysis was performed using SPSS, with descriptive statistics to describe respondent characteristics, followed by bivariate tests (Chi-Square) to examine the association between breastfeeding, low birth weight status, and other variables and pneumonia. Odds ratios (OR) and 95% confidence intervals were used to measure the strength of the association, with a p-value  $< 0.05$  as the significance level. This approach allows for a comprehensive assessment of the association between infant pneumonia, breastfeeding, and low birth weight status using representative national health survey data.

## RESULTS AND DISCUSSION

This study analyzed data from the 2023 Indonesian Health Survey (SKI), which included 28,610 infants aged 1 year and under. This analysis presents the distribution of provincial origins, demographic characteristics, and infant health conditions, including pneumonia, diarrhea, low birth weight (LBW), and breastfeeding status.

The distribution of respondents shows that Central Java province contributed the largest number of infants to the survey, while Highlands Papua recorded the fewest. Table 1 presents a detailed provincial distribution.

Table 1. Distribution of Respondents by Province (Infants  $\leq 1$  Year) in the 2023 Indonesian Health Survey

No	Province	Frequency (n)	Percentage (%)
1	Aceh	1285	4.5
2	Sumatera Utara	1784	6.2
3	Sumatera Barat	1237	4.3
4	Riau	818	2.9
5	Jambi	484	1.7
6	Sumatera Selatan	912	3.2
7	Bengkulu	469	1.6
8	Lampung	797	2.8
9	Kepulauan Bangka Belitung	299	1.0
10	Kepulauan Riau	385	1.3
11	DKI Jakarta	380	1.3
12	Jawa Barat	1839	6.4
13	Jawa Tengah	2167	7.6
14	DI Yogyakarta	215	0.8
15	Jawa Timur	1811	6.3
16	Banten	513	1.8
17	Bali	549	1.9
18	Nusa Tenggara Barat	735	2.6
19	Nusa Tenggara Timur	1381	4.8
20	Kalimantan Barat	601	2.1
21	Kalimantan Tengah	607	2.1
22	Kalimantan Selatan	656	2.3
23	Kalimantan Timur	619	2.2
24	Kalimantan Utara	337	1.2
25	Sulawesi Utara	611	2.1
26	Sulawesi Tengah	790	2.8
27	Sulawesi Selatan	1525	5.3
28	Sulawesi Tenggara	1131	4.0
29	Gorontalo	332	1.2
30	Sulawesi Barat	453	1.6
31	Maluku	620	2.2
32	Maluku Utara	496	1.7
33	Papua Barat	404	1.4
34	Papua Barat Daya	380	1.3
35	Papua	430	1.5
36	Papua Selatan	202	0.7
37	Papua Tengah	224	0.8
38	Papua Pegunungan	132	0.5
Total	—	28.610	100.0

The distribution of infant characteristics shows that male infants dominate the study population, while the distribution of residence is almost balanced between urban and rural areas. The prevalence of pneumonia was low, at less than one percent. Table 2 summarizes the demographic and health characteristics of infants.

Table 2. Demographic and Health Characteristics of Infants in the 2023 Indonesian Health Survey

<b>Variable</b>	<b>Frequency (n)</b>	<b>Percentage (%)</b>
<b>Pneumonia</b>		
Yes	265	0.9
No	28.345	99.1
<b>Sex</b>		
Male	14.750	51.6
Female	13.860	48.4
<b>Residence</b>		
Urban	14.478	50.6
Rural	14.132	49.4
<b>Low Birth Weight (LBW)</b>		
Yes	1.646	5.8
No	26.964	94.2
<b>Breastfeeding Status</b>		
Yes	23.939	83.7
No	4.671	16.3
<b>Diarrhea</b>		
Yes	808	2.8
No	27.802	97.2

The association analysis indicates that several factors are significantly associated with pneumonia. Infants with low birth weight (LBW) show a more than twofold higher risk of pneumonia compared to infants with normal birth weight. Breastfeeding status provides significant protection, while diarrhea increases the risk. Male gender and urban residence also show a trend toward a higher risk of pneumonia. Table 3 summarizes the association of each variable with the incidence of pneumonia in infants.

This study, involving 28,610 infants under one year old, showed that the majority of respondents came from Central Java (7.6%), West Java (6.4%), and North Sumatra (6.2%). The survey provided greater representation in densely populated areas, thus reflecting Indonesia's broader demographic diversity. Uneven geographic distribution also influences variations in pneumonia prevalence. Regions such as the Highlands of Papua, which accounted for only 0.5% of total respondents, had very little representation, even though areas with limited healthcare access, such as this, have the potential to have a higher pneumonia prevalence<sup>19,20</sup>.

The results of the 2023 health survey showed that the prevalence of pneumonia in infants reached 0.9%. Infants with low birth weight (LBW) showed a significantly higher odds of pneumonia compared to infants with normal birth weight (OR: 2.425; 95% CI: 1.688–3.483). These findings are consistent with research by Addisu et al. (2021), which showed that vulnerable physical conditions, such as low birth weight (LBW) and exposure

to unhealthy environments, can increase the risk of respiratory tract infections<sup>21</sup>. Conversely, breastfeeding has been shown to protect against pneumonia. Breastfed infants have a lower risk of pneumonia (OR: 0.590; 95% CI: 0.447–0.778). This finding supports the research of Abebaw and Damtie (2022), which stated that exclusive breastfeeding can reduce the prevalence of pneumonia by strengthening the infant's immune system<sup>6</sup>.

Table 3. Association Between Pneumonia and Infant Characteristics

<b>Variables</b>	<b>Pneumonia Yes (n=265)</b>	<b>Pneumonia No (n=28.345)</b>	<b>p-value</b>	<b>OR (95% CI)</b>
<b>Sex</b>				
Male	168 (63.4%)	14.582 (51.4%)	0.000	1.658 (1.289–
Female	97 (36.6%)	13.763 (48.6%)		2.132)
<b>Residence</b>				
Urban	163 (61.5%)	14.315 (50.5%)	0.001	1.505 (1.173–
Rural	102 (38.5%)	14.030 (49.5%)		1.931)
<b>Low Birth Weight (LBW)</b>				
Yes	35 (13.2%)	1.611 (5.7%)	0.000	2.425 (1.688–
No	230 (86.8%)	26.734 (94.3%)		3.483)
<b>Breastfeeding</b>				
Yes	195 (73.6%)	23.744 (83.8%)	0.000	0.590 (0.447–
No	70 (26.4%)	4.601 (16.2%)		0.778)
<b>Diarrhea</b>				
Yes	15 (5.7%)	793 (2.8%)	0.008	2.051 (1.211–
No	250 (94.3%)	27.552 (97.2%)		3.475)

Demographic analysis showed that Male infants had higher odds of pneumonia than female infants (OR: 1.658; 95% CI: 1.289–2.132). These findings align with Casimir's (2010) research, which explains that differences in the immune response to respiratory infections between male and female infants contribute to this variation in risk<sup>22</sup>. In addition, infants living in urban areas had higher odds of pneumonia than those living in rural areas (OR: 1.505; 95% CI: 1.173–1.931). Environmental factors such as exposure to air pollution, particularly from solid fuels, are believed to increase the risk of respiratory disease in infants<sup>23</sup>.

An infant with a history of diarrhea showed significantly higher odds of pneumonia (OR: 2.051; 95% CI: 1.211–3.475). Diarrhea can weaken an infant's immune system through impaired nutrient absorption and dehydration, increasing the risk of secondary infections such as pneumonia<sup>24</sup>. Research by Akinyemi and Morakinyo (2018) also confirms that pre-existing health conditions, including diarrhea, can influence an infant's susceptibility to acute respiratory infections<sup>25</sup>.

Efforts to prevent pneumonia in infants should focus on promoting exclusive breastfeeding, monitoring for low birth weight (LBW), and improving environmental hygiene. Good nutrition also plays a crucial role in preventing infectious diseases, as explained by Calder PC and Jackson AA (2000)<sup>8</sup>. Controlling air quality, especially in urban areas, should be a priority because indoor air pollution has been shown to increase the risk of pneumonia<sup>26</sup>. Furthermore, public education regarding the importance of

maintaining a healthy environment and reducing exposure to cigarette smoke needs to be continuously improved.

This study has several limitations. This study did not apply survey weighting and multivariable adjustment, which may limit the precision of the estimated associations. The observational, cross-sectional design allows only the observation of relationships between components, without directly inferring causality. Several important variables, such as breastfeeding and history of diarrhea, rely on reports from mothers or guardians, potentially introducing recall bias. The uneven distribution of respondents across provinces, for example, the low number of respondents from Highlands Papua (0.5%), may reduce the accuracy of prevalence estimates in that region. Furthermore, this study did not include several other environmental factors that could influence pneumonia, such as socioeconomic status, home smoking habits, and air quality. This study design also does not allow for evaluating the long-term effects of risk factors, such as low birth weight (LBW) or breastfeeding, on pneumonia risk.

## CONCLUSION

This study reports a pneumonia prevalence of 0.9% among infants in Indonesia, based on a 2023 survey of 28,610 respondents. This analysis identified that low birth weight infants and infants with a history of diarrhea showed higher odds of pneumonia, while breastfed infants had a lower risk. The results also show that male infants and infants living in urban areas showed higher odds of pneumonia. These findings confirm that biological, environmental, and behavioral factors are associated with pneumonia. This study encourages the government and health facilities to strengthen monitoring of at-risk infants, increase breastfeeding promotion, improve sanitation and practices to prevent diarrhea, and reduce exposure to air pollution, especially in urban areas. This research ultimately provides a scientific basis for improving infant health policies and increasing the equity of health services across Indonesia.

## ACKNOWLEDGEMENT

The author would like to thank those who have helped carry out this research.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## REFERENCES

1. World Health Organization. World health report: changing history [electronic resource]. Geneva: WHO; 2004. Accessed on 2026 Feb 7. <https://www.who.int/publications/i/item/world-health-report-2004>
2. Shibata T, Wilson JL, Watson LM, LeDuc A, Meng C, La Ane R, Maidin A. Childhood acute respiratory infections and household environment in an eastern Indonesian urban setting. *Int J Environ Res Public Health*. 2014;11(12):12190–203. <https://doi.org/10.3390/ijerph111212190>
3. Nirmolia N, Mahanta TG, Boruah M, Rasaily R, Kotoky RP, Bora R. Prevalence and risk factors of pneumonia in under-five children living in slums of Dibrugarh town. *Clin Epidemiol Glob Health*. 2018;6(1):1–4. <https://doi.org/10.1016/j.cegh.2017.07.004>

4. Tazinya AA, Halle-Ekane GE, Mbuagbaw LT, Abanda M, Atashili J, Obama MT. Risk factors for acute respiratory infections in children under five years attending the Bamenda Regional Hospital in Cameroon. *BMC Pulm Med.* 2018;18(7):1–8. <https://doi.org/10.1186/s12890-018-0579-7>
5. Lutpiatina L, Sulistyorini L, Yudhastuti R, Notobroto HB. Prediction of Toddlers Acute Respiratory Infection (ARI) to Become Pneumonia in Martapura Catchment Area, Banjar District, Indonesia. *Glob Pediatr Health.* 2024 Feb 23;11:2333794X241227694. doi: 10.1177/2333794X241227694.
6. Abebaw B, Damtie D. Pneumonia prevalence and associated risk factors among under-five children in Goncha Siso Enesie District, Northwest Ethiopia. *Adv Public Health.* 2022;2022:1–8. <https://doi.org/10.1155/2022/6497895>
7. Fakh A, Okafor C, Yusuf S, Mahmoud S, Masud M, Obeagu E, Nyabukika A, Omar M, Sheha K, Khamis A. Evaluation of risk factors of pneumonia in children under five years old at Mnazi Mmoja Hospital-Zanzibar. *Bull Environ Pharmacol Life Sci.* 2021;10:69–75.
8. Calder PC, Jackson AA. Undernutrition, infection and immune function. *Nutr Res Rev.* 2000;13:3–29.
9. Le Doare K, Holder B, Bassett A, Pannaraj PS. Mother's milk: a purposeful contribution to the development of the infant microbiota and immunity. *Front Immunol.* 2018;9:361. <https://doi.org/10.3389/fimmu.2018.00361>
10. Lynn B. Keep in touch: the importance of touch in infant development. *Infant Obs.* 2005;8:115–23. <https://doi.org/10.1080/13698030500171530>
11. Tessema ZT, Tamirat KS, Teshale AB, Tesema GA. Prevalence of low birth weight and its associated factors at birth in Sub-Saharan Africa: a generalized linear mixed model. *PLoS One.* 2021;16(3):e0248417.
12. Demelash H, Motbainor A, Nigatu D, Gashaw K, Melese A. Risk factors for low birth weight in Bale Zone hospitals, South-East Ethiopia: a case-control study. *BMC Pregnancy Childbirth.* 2015;15:264. doi:10.1186/s12884-015-0677-y.
13. Dinas Kesehatan Provinsi Kalimantan Selatan. *Profil Kesehatan Provinsi Kalimantan Selatan 2019.* Banjarmasin: Dinkes Kalsel; 2020.
14. Dinas Kesehatan Provinsi Kalimantan Selatan. *Profil Kesehatan Provinsi Kalimantan Selatan 2020.* Banjarmasin: Dinkes Kalsel; 2021.
15. Kleinman RE, Greer FR, editors; American Academy of Pediatrics Committee on Nutrition. *Pediatric nutrition.* 8th ed. Itasca, IL: American Academy of Pediatrics; 2019.
16. Gidrewicz DA, Fenton TR. A systematic review and meta-analysis of the nutrient content of preterm and term breast milk. *BMC Pediatr.* 2014;14:216.
17. Brown JVE, Walsh V, McGuire W. Formula versus maternal breast milk for feeding preterm or low birth weight infants. *Cochrane Database Syst Rev.* 2019;8:CD002972. doi:10.1002/14651858.CD002972.pub3.
18. Narayanan I, Prakash K, Prabhakar AK, Gujral VV. A planned prospective evaluation of the anti-infective property of varying quantities of expressed human milk. *Acta Paediatr.* 1982;71(3):441–5.
19. Dahlan Z. Pneumonia: definition and etiology. *Indones J Med.* 2000;55(2):123–30.
20. Mardjanis S. Epidemiology of pneumonia. *J Pulm Med.* 2008;12(3):145–52.

21. Addisu A, Getahun T, Deti M, Negesse Y, Mekonnen B. Association of acute respiratory infections with indoor air pollution from biomass fuel exposure among under-five children in Jimma Town, Southwestern Ethiopia. *J Environ Public Health*. 2021;2021:7112548. doi:10.1155/2021/7112548.
22. Casimir GJ, Lefèvre N, Corazza F, Duchateau J, Chamekh M. Why are boys more vulnerable to respiratory infections? *Acta Paediatr*. 2010;99(3):401–3.
23. Acharya P, Mishra SR, Berg-Beckhoff G. Solid fuel in kitchen and acute respiratory tract infection among under-five children: evidence from Nepal demographic and health survey 2011. *J Community Health*. 2015;40(3):515–21.
24. Iwasaki A, Pillai PS. Innate immunity to influenza virus infection. *Nat Rev Immunol*. 2014;14(5):315–28.
25. Akinyemi JO, Morakinyo OM. Household environment and symptoms of childhood acute respiratory tract infections in Nigeria, 2003–2013. *BMC Infect Dis*. 2018;18:296.
26. Chen J, Ho SSH, Cao J. Impact of cigarette smoke on the respiratory tract. *J Respir Res*. 2020;25(4):215–23.