

LOW BIRTH WEIGHT AND CHILDHOOD PNEUMONIA IN SUMATRA, INDONESIA: A CROSS-SECTIONAL ANALYSIS OF THE 2023 INDONESIAN HEALTH SURVEY

Aulia Putri¹, Ratno Widoyo^{1*}, Defriman Jafri¹

¹Faculty of Public Health, Andalas Universitas Andalas, Padang, Indonesia

Abstract

Low birth weight (LBW) is a well-established early-life biological risk factor for respiratory infections; however, subnational evidence examining its role in childhood pneumonia in Indonesia remains limited. This study aimed to examine the association between low birth weight and pneumonia among children aged 12–59 months in Sumatra, Indonesia, while accounting for demographic, health service, and environmental factors. A cross-sectional study was conducted using data from the 2023 Indonesian Health Survey (IHS). The analysis included 21,466 children aged 12–59 months residing in Sumatra. Pneumonia status and low birth weight were defined according to the SKI standard definitions. Multivariable logistic regression analyses were performed using sampling weights to account for the complex survey design. Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) were reported. The prevalence of pneumonia among children aged 12–59 months in Sumatra was 1.0%. Children with a history of low birth weight had markedly higher odds of pneumonia compared with those born with normal birth weight (aOR 14.9; 95% CI 9.2-24.1). Household cooking fuel use was identified as a confounding factor, but not as an interaction. Other factors, including vitamin A supplementation, immunization status, and area of residence, were not identified as confounding or interacting factors. Low birth weight is a strong determinant of pneumonia among children aged 12–59 months in Sumatra. Reducing childhood pneumonia requires integrated strategies addressing both early-life biological vulnerability and modifiable household environmental exposures.

Keywords: Low birth weight; Pneumonia; Children under five; Household air pollution; Cooking fuel;

Corresponding Author: Ratno Widoyo
Email: ratnowidoyo@ph.unand.ac.id

Article Received : February 21, 2026
Article Revised : March 25, 2026
Article Published : March 31, 2026

INTRODUCTION

Children under five years old are highly impacted by pneumonia due to the mortality and morbidity it causes globally, specifically in developing nations (1,2). The World Health Organization (WHO) stated that pneumonia was responsible for 740,180 deaths of children under five years old (3,4). This number accounts for 14% of deaths in this age group (5). Integrated Global Action Plan for Pneumonia and Diarrhea (GAPPD) has been implemented; however, due to the lack of development in many nations to attain socioeconomic stability and environmental health, pneumonia remains a global health issue (6,7).

Pneumonia has been recorded as one of the main reasons for the mortality of children under the age of five (8,9). Approximately 19,000 children under the age of five died because of pneumonia (10). The Indonesia Health Survey (IHS) or Survey Kesehatan Indonesia (SKI) 2023 recently reported a 15% increase in pneumonia prevalence among children under five from 4.8% in 2018 to 15% in 2023 (11). The increase in percentages may also result from improvements in the measurement of underreporting, increased levels of detection and reporting, and caregivers' understanding of the illness (12,13). However, changes in measurement across collections also affect the overall prevalence rate. This leads to the

conclusion that the burden of pneumonia in children continues to be a worldwide challenge that is not yet solved and needs to be addressed.

In Indonesia, Sumatra, along with Papua and Sulawesi, ranks among the regions with the highest prevalence of pneumonia in children under five, reaching 14.3% (11). Sumatra also demonstrates substantial epidemiological heterogeneity across provinces and districts, particularly in terms of socioeconomic development, urban-rural distribution, environmental conditions, and access to maternal and child health services (14). These variations may contribute to differences in the distribution of childhood pneumonia and its associated risk factors across the region.

Previous studies have identified several determinants of childhood pneumonia, including poor indoor air quality due to polluted cooking fuels, household overcrowding, inadequate waste disposal, low immunization coverage, vitamin A deficiency, and malnutrition (15,16). Furthermore, these environmental and behavioral factors, biological conditions during early life, also play an important role in increasing susceptibility to respiratory infections among children (17,18). One of the most important biological risk factors is low birth weight, defined as a birth weight below 2,500 grams, which has consistently been associated with increased morbidity and mortality from infectious diseases during infancy and early childhood (19,20).

Research further examines the link between LBW and childhood pneumonia, specifically in Indonesia, and primarily in the context of nationally representative surveys that account for complex survey methods and regional differences. Nonetheless, while the area is a significant contributor to the country's burden of childhood pneumonia, there remains a paucity of subregional studies in high-burden regions such as Sumatra. Addressing this gap is essential to the design of comprehensive early-life interventions in tandem with environmental and health system enhancements.

The objective of this study is to examine the association between low birth weight and pneumonia in children 12-59 months old in Sumatra. The study analyses data from the Indonesian Health Survey 2023 to obtain information from a subnational perspective. The study includes demographic, health service access, and environmental factors that can inform the evidence base for childhood pneumonia prevention strategies.

METHODS

The study design comprises secondary data from the 2023 Indonesian Health Survey (Survei Kesehatan Indonesia, SKI), a cross-sectional survey of the entire nation administered by the Ministry of Health of Indonesia. The SKI utilizes a multistage, stratified cluster sampling design, and data are collected from each province on the health and behaviours of the population, as well as the accessibility of health services.

The study population includes children aged 12 to 59 months residing in the Sumatra region at the time of the survey. The individual child was the unit of analysis. Children with missing or incomplete data on pneumonia status or birth weight were excluded from the study. From 10 provinces and 154 districts/cities in Sumatra, a total of 21,466 children were included in the analysis.

The outcome variable was pneumonia status, defined as caregiver-reported information from the one year before the interview that a child had been diagnosed with pneumonia by a

health care provider and/or had symptoms of fever, cough, and difficulty breathing. Diagnostic misclassification is a possibility with caregiver-reported diagnoses; however, this method is frequently employed in extensive population surveys and provides a significant understanding of the population-level disease burden.

The primary exposure variable is low birth weight, defined as birth weight less than 2,500 grams. Maternal recall or child health records, if available, were used to obtain birth weight data. While maternal recall may be vulnerable to recall bias, the validity of population-based surveys has been demonstrated in previous studies.

Possible confounding variables were chosen a priori, as there are available literature and a conceptual framework that describes the link between biological vulnerability, environmental exposure, health service variables, and childhood pneumonia. These include: child sex, vitamin A supplementation received, basic immunization completeness, PCV immunization status, urban or rural residence, household crowding, primary cooking fuel, and waste disposal.

Each analysis incorporated the sampling weights, as well as the stratification and clustering variables, reflecting the SKI complex sampling design. Descriptive statistics were utilized to characterize the study population. Bivariate analyses were conducted to examine the associations between LBW and Pneumonia, and between covariates and pneumonia.

To assess the association between LBW and Pneumonia, multivariable logistic regression was performed while controlling for confounding factors. All possible confounder variables were tested. A variable is declared a confounder if AORs increase or decrease the crude OR for the relationship between LBW and pneumonia by more than 10%. Those declared as confounder variables are then tested for interaction. If interaction is specified, the aORs would be reported within strata. The final results presented adjusted odds ratios (aORs) with 95% confidence intervals (CIs). The research employed secondary, anonymized data, so additional ethical clearance or informed consent was not required. The relevant National Ethics Committee has approved the primary data used for the analysis, which were obtained from the 2023 Indonesian Health Survey.

RESULTS

This analysis included 21,466 children aged 12–59 months living in Sumatra. The overall prevalence of pneumonia among children under five years of age was 1.0% (Table 1). Characteristics of children aged 12–59 months in Sumatra were low birth weight (3.4%), slightly more boys than girls, 66.3% incomplete vitamin A supplementation, 81.8% incomplete basic immunization, 77.8% incomplete PCV immunization, a majority living in rural areas, a majority living in crowded households, primarily families using non-polluted cooking fuel, and a majority of families incinerating waste.

The prevalence of pneumonia varied across child and household characteristics. Pneumonia cases were observed among male children compared with female children. Children with a history of low birth weight had a higher prevalence of pneumonia than children born with normal birth weight. Higher pneumonia prevalence was also observed among children who received vitamin A supplementation, had incomplete basic immunization, and had not received the pneumococcal conjugate vaccine (PCV). Regarding environmental characteristics, pneumonia prevalence was higher among children living in households that

used polluted cooking fuels than among those using clean fuels and among families with incinerating waste. Differences in pneumonia prevalence by area of residence (urban versus rural) and by household crowding were minimal.

Table 1. Characteristics of children 12-59 months in Sumatra

Variables	f (21.466)	% (100)
Pneumonia		
Pneumonia	206.3	1
No Pneumonia	21 259.7	99
Low Birth Weight		
LBW	734.5	3.4
No LBW	20 731.5	96.6
Gender		
Male	10 927.1	50.9
Female	10 538.1	49.1
Vitamin A Completeness		
Incomplete	14 236.5	66.3
Complete	7 229.5	33.7
Complete Basic Immunization		
Incomplete	17 561.5	81.8
Complete	3 904.5	18.2
PCV Immunization Status		
Incomplete	16 702.0	77.8
Complete	4 764.0	22.2
Residence Area		
Rural	16 617.5	77.4
Urban	4 848.5	22.6
Housing Density		
Dense	19 680.6	91.7
Not Dense	1 785.4	8.3
Main Fuel		
Causes Pollution	691.3	3.2
Not Cause Pollution	20 774.7	96.8
Waste Management		
Incinerated	13 907.5	64.8
Other	7 558.5	35.2
Total	21 466.0	100

Bivariate analyses in Table 2 showed that male sex, low birth weight, lack of vitamin A supplementation, incomplete basic immunization, absence of PCV vaccination, and cooking fuels were significantly associated with pneumonia ($p < 0.05$). Low birth weight showed the strongest association with pneumonia among the variables.

Table 2. Analysis of bivariate risk factors of pneumonia in children aged 12-59 months in Sumatra

Variables	Pneumonia				OR	95% CI	p-value
	Yes		No				
	f	%	f	%			
Low Birth Weight							
LBW	62.7	8.5	671.7	91.5	13.4	8.3-21.5	0.001
No LBW	143.6	0.7	20 587.9	99.1			
Gender							
Male	149.6	1.4	10 777.5	98.6	2.6	1.6-4.1	0.001
Female	56.7	0.5	10 482.2	99.5			
Vitamin A Completeness							
Incomplete	114.2	0.8	14 122.2	99.2	0.6	0.4-0.9	0.025
Complete	92.1	1.3	7 137.5	98.7			
Complete Basic Immunization							
Incomplete	166.3	0.9	17 395.2	99.1	0.9	0.6-1.5	0.745
Complete	40.0	1.0	3 864.5	99.0			
PCV Immunization Status							
Incomplete	194.1	1.2	16 507.8	98.8	4.6	2.2-9.6	0.001
Complete	12.2	0.3	4 751.8	99.7			
Residence Area							
Rural	163.0	1.0	16 454.5	99.0	1.1	0.6-1.9	0.732
Urban	43.3	0.9	4 805.2	99.1			
Housing Density							
Dense	186.0	0.9	19 494.6	99.1	0.8	0.4-1.5	0.549
Not Dense	20.3	1.1	1 765				
Main Fuel							
Causes Pollution	36.3	5.2	654.9	94.8	6.7	3.6-12.4	0.001
Not Cause Pollution	170.0	0.8	20 604.7	99.2			
Waste Management							
Incinerated	162.7	1.2	13 744.9	98.8	2.0	1.2-3.4	0.005
Other	43.7	0.6	7 513.8	99.4			

Based on a threshold of greater than 10% OR for the association between low birth weight and pneumonia, cooking fuel was identified as a confounder (Table 3). In Table 3, we tested whether the covariate variable acted as a confounder. In Table 3, we assessed whether the covariate variables acted as confounders. The “+” sign indicates that the variable was included in the consecutive model. After adjusting for the low birth weight variable with gender, vitamin A supplementation status, complete basic immunization, PCV immunization status, residence area, housing density, and waste management, the delta odds ratio is below 10% compare with the crude odds ratio. The confounding variable was also tested for interaction. There was no statistical interaction found between low birth weight and cooking fuel.

Table 3 Identification of Confounding Variables

Variable	P1	P2	P3	P4	P5	P6	P7	P8*	P9
Low Birth Weight	+	+	+	+	+	+	+	+	+
Gender		+							
Vitamin A Completeness			+						
Complete Basic Immunization				+					
PCV Immunization Status					+				
Residence Area						+			
Housing Density							+		
Main Fuel								+	
Waste Management									+
OR	13.4	13.5	13.7	13.4	12.6	13.4	13.4	14.9	13.5
Delta OR (%)		0.69	2.38	0	-6.1	0	0	11.4	0.78

P1-P9: Logistic regression model

*model with a confounding variable

Table 4. Result of Multivariate Analysis

Variabel	OR	95% CI		p-value	Nagelkerke
		Lower	Upper		
Low Birth Weight	14.9	9.2	24.1	0.001	0.119
Main Fuel	8.1	4.2	15.5	0.001	

In the multivariable logistic regression model (Table 4), low birth weight remained significantly associated with pneumonia after adjustment for potential confounders. Children with a history of low birth weight had substantially higher odds of pneumonia compared with children born with normal birth weight (adjusted odds ratio 14.9; 95% CI 9.2-24.1). Use of cooking fuels was also independently associated with pneumonia in the adjusted model. Children residing in households using types of cooking fuels had higher odds of pneumonia than those living in households using clean fuels.

DISCUSSION

This study indicates that low birth weight is a risk factor for pneumonia among children aged 12–59 months in Sumatra, Indonesia. The risk remains high even after controlling for a range of socio-demographic, nutritional, immunization, and environmental factors. In addition, household use of cooking fuels remained independently associated with pneumonia and acted as a confounding factor. No interaction between LBW and cooking fuel, indicating that biological vulnerability and environmental exposure contribute to pneumonia risk through independent pathways.

In this study, we found significantly fewer cases of pneumonia compared to the 2023 national SKI report. According to the operational definition of SKI, pneumonia in children aged 12-59 months can be identified based on a history of diagnosis and three symptoms (fever, cough, and difficulty breathing) experienced by the toddler over the past year. Based on the diagnosis, 0.6% had pneumonia. Based on symptoms, 0.4% had pneumonia, with 12.5% having fever, 11.0% having fever, and 0.6% having difficulty breathing with or without chest pain.

The strong association between LBW and Pneumonia observed in this study is consistent with previous evidence from low- and middle-income countries (17). Several studies consistently reported higher risks of acute lower respiratory infections and pneumonia among children born with LBW (21). The risk ranges from 2- to 5-fold, depending on age group, outcome definition, and study design (22,23) .

Biologically, LBW reflects impaired fetal growth and suboptimal intrauterine development, both of which are associated with long-term structural and functional deficits in the respiratory and immune systems (24,25). Specifically, LBW can reflect impaired lung volume development, impaired alveolar development, decreased lung reserve, and immaturity of innate and adaptive immune responses (26,27). In particular, deficits in cell-mediated immunity and reduced mucosal defense mechanisms increase susceptibility to lower respiratory tract infections during early childhood (28). These physiological limitations may reduce the child's capacity to respond effectively to infectious pathogens, thereby increasing the likelihood of pneumonia.

The magnitude of association identified in this study appears higher than that reported in several previous Indonesian studies. This finding may reflect that early biological disadvantages associated with LBW are compounded by persistent socioeconomic and environmental exposures (29). Chronic exposure to poor housing conditions, household air pollution, overcrowding, and limited access to health services may intensify the adverse effects of LBW on respiratory health. In addition, variations in case ascertainment, residual confounding, and unmeasured contextual factors may also contribute to differences in effect estimates across studies. Slightly lower immunization coverage in Sumatra compared with national averages may further increase susceptibility to respiratory infections and partially explain the stronger observed association. Immunization coverage also might play a role in this situation (30,31).

Consistent with previous evidence, our findings indicate that children with LBW have substantially higher odds of developing pneumonia than children with normal birth weight (32,33). The elevated risk observed in this study exceeds that reported in several other Indonesian settings. For example, a study conducted in West Java reported that toddlers with LBW had an 8.9-fold increased risk of pneumonia (34). At the national level, analysis of the same 2023 Indonesian Health Survey data for infants under one year reported a more modest odds ratio of 2.43 (35). Other subnational studies in high-prevalence areas of Indonesia have reported risk ratios around 3.27 (9).

Household air pollution resulting from the use of polluting cooking fuels may play a dual role in the pathway linking LBW and pneumonia (36–38). Exposure to household air pollution during pregnancy has been associated with impaired fetal growth and increased risk of LBW, while postnatal exposure contributes directly to respiratory infections among children. Consequently, cooking fuel type may act both as an upstream determinant of LBW and as a downstream determinant of childhood pneumonia. The identification of cooking fuel as a confounding variable highlights the interconnected nature of prenatal and postnatal environmental exposures in shaping childhood respiratory health outcomes (39,40).

The cooking fuel type had no statistically significant interaction between LBW and household fuel use. This finding suggests that the effect of LBW on pneumonia risk does not differ according to household fuel type, and similarly, the effect of household air pollution is

not modified by birth weight status. In other words, LBW and household air pollution appear to operate as independent risk factors rather than synergistically amplifying each other's effects.

The several strengths of this study are the use of a large and regionally representative dataset and the application of appropriate analytical approaches that accounted for the complex survey design. Nevertheless, several limitations such as: First, the cross-sectional nature of the study precludes causal interpretation of the observed associations. Second, residual confounding from unmeasured variables cannot be completely excluded. Third, information on pneumonia status and birth weight was partly based on caregiver recall, which may have introduced recall bias and outcome misclassification. These limitations should be considered when interpreting the findings.

CONCLUSION AND RECOMMENDATION

Among children aged 12–59 months in Sumatra, Indonesia, low birth weight was the strongest predictor of pneumonia, and household use of polluted cooking fuels was an additional independent risk factor. The association between low birth weight and pneumonia was partially confounded by household cooking fuel use. Still, no interaction was observed, indicating that biological vulnerability and household air pollution operate through independent pathways. These findings emphasize the importance of addressing both early-life biological risk and modifiable household environmental exposures to reduce the burden of childhood pneumonia.

Efforts to reduce children's exposure to household air pollutants, particularly among children with low birth weight, may reduce the risk of pneumonia. Targeted education and counseling for mothers and families regarding the health risks of household air pollution for children with low birth weight should be emphasized, especially in households using polluting cooking fuels.

Acknowledgement

The authors appreciate to Indonesia Ministry of Health and Universitas Andalas for their support in this study.

Funding

This study was supported by Universitas Andalas with grand number 301/UN16.19/PT.01.03/PSS/2025.

REFERENCES

1. UNICEF. Pneumonia in Children Statistics [Internet]. UNICEF. 2024 [cited 2026 Jan 20]. Available from: <https://data.unicef.org/topic/child-health/pneumonia/>
2. Odoom A, Opoku-Asare B, Donkor ES. The Burden of Hospitalization Due to Klebsiella pneumoniae–Associated Pneumonia in Children Under 5 Years in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis. *Heal Sci Reports*. 2025;8(11). <https://doi.org/10.1002/hsr2.71395>
3. World Health Organization. Pneumonia In Children [Internet]. World Health Organization. 2022 [cited 2026 Jan 20]. Available from: <https://www.who.int/news-room/fact-sheets/detail/pneumonia>

4. Wang M. Clinical characteristics of pediatric pneumonia: a retrospective study. *Am J Transl Res.* 2025;17(6):4642–50. <https://doi.org/10.62347/NMGN1230>
5. Kifle M, Yadeta TA, Debellia A, Mussa I. Determinants of pneumonia among under-five children at Hiwot Fana specialized hospital, Eastern Ethiopia: unmatched case-control study. *BMC Pulm Med.* 2023;23(1):1–11. <https://doi.org/10.1186/s12890-023-02593-3>
6. Langefeld K. Pneumonia Remains Leading Cause of Child Mortality [Internet]. Global Initiative for Chronic Obstructive Lung Disease - GOLD. 2025 [cited 2026 Jan 20]. Available from: <https://goldcopd.org/pneumonia-remains-leading-cause-of-child-mortality/>
7. The Lancet Respiratory Medicine. Pneumonia: a neglected global threat. *Lancet Respir Med.* 2025;13(4):289. [https://doi.org/10.1016/S2213-2600\(25\)00087-6](https://doi.org/10.1016/S2213-2600(25)00087-6)
8. Keleb A, Sisay T, Alemu K, Ademas A, Lingerew M, Kloos H, et al. Pneumonia remains a leading public health problem among under-five children in peri-urban areas of north-eastern Ethiopia. *PLoS One.* 2020;15(9):e0235818. <https://doi.org/10.1371/journal.pone.0235818>.
9. Sutriana VN, Sitaresmi MN, Wahab A. Risk factors for childhood pneumonia: a case-control study in a high prevalence area in Indonesia. *Clin Exp Pediatr.* 2021;64(11):588–95. <https://doi.org/10.3345/cep.2020.00339>
10. Ministry of Health Republic of Indonesia. National Action Plan for Pneumonia and Diarrhea Control 2023-2030. Jakarta; 2023.
11. Badan Kebijakan Pembangunan Kesehatan. Indonesia Health Survey (IHS) 2023 [Internet]. BKKP Kemenkes. 2023 [cited 2026 Jan 20]. Available from: <https://www.badankebijakan.kemkes.go.id/hasil-ski-2023/>
12. Gelagay AA, Azale T, Gezie LD, Tigabu Z, Alemu K. High proportion of pneumonia morbidity and risk factors in sick under-five children, northwest Ethiopia: a health facility based cross-sectional study. *Sci Rep.* 2026;16(1):7039. <https://doi.org/10.1038/s41598-026-37920-1>
13. Shi H, Wang T, Zhao Z, Norback D, Wang X, Li Y, et al. Prevalence, risk factors, impact and management of pneumonia among preschool children in Chinese seven cities: a cross-sectional study with interrupted time series analysis. *BMC Med.* 2023;21(1):1–14. <https://doi.org/10.1186/s12916-023-02951-2>
14. Purnama TB, Wagatsuma K, Pane M, Saito R. Effects of the Local Environment and Nutritional Status on the Incidence of Acute Respiratory Infections Among Children Under 5 Years Old in Indonesia. *J Prev Med Public Heal.* 2024;57(5):461–70. <https://doi.org/10.3961/jpmph.24.246>
15. Lu Y. Determinants of childhood pneumonia: a retrospective hospital-based analysis. *Front Med.* 2025;12(October):1–10. <https://doi.org/10.3389/fmed.2025.1709403>
16. M S, Vaithilingan S. Childhood Pneumonia in Low- and Middle-Income Countries: A Systematic Review of Prevalence, Risk Factors, and Healthcare-Seeking Behaviors. *Cureus.* 2024;16(4). <https://doi.org/10.7759/cureus.57636>
17. Abubakar FI, Oche OM, Kaoje AU, Garba BI, Abubakar MJ, Ahmed HK. Prevalence and associated risk factors of acute respiratory tract infections among under-five children in a tertiary hospital in Nigeria. *BMC Pediatr.* 2025;25(1). <https://doi.org/10.1186/s12887-025-06193-4>
18. Polo-Pucho DA, Gonzales-Carrillo JJ, Arce-Huamani MA. Factors Associated with Acute Respiratory Infections in Children Under Five Years Old: Analysis of the Demographic and Family Health Survey. *Children.* 2025;12(9):1–16. <https://doi.org/10.3390/children12091242>
19. Xu X, Deng Y, Han J, Wang J, Huang R, Zhao X. Analysis of risk factors contributing to neonatal pneumonia in low birth weight neonates. *Front Pediatr.* 2025;13(September):1–

8. <https://doi.org/10.3389/fped.2025.1620077>
20. Karmany PAW, Rahardjo SS, Murti B. Effect of Low Birth Weight on the Risk of Pneumonia in Children Under Five: Meta-Analysis. 2020;57126. <https://doi.org/10.26911/the7thicph.01.61>
21. Puspamaniar VA, Setyoningrum RA, Susanti D. Low Birth Weight as Risk Factor of Pneumonia Child in Primary Health Care of Surabaya. JUXTA J Ilm Mhs Kedokt Univ Airlangga. 2019;10(2):61. <https://doi.org/10.20473/juxta.V10I22019.61-63>
22. Wilkes C, Bava M, Graham HR, Duke T. What are the risk factors for death among children with pneumonia in low and middle-income countries? A systematic review. J Glob Health. 2023;13. <https://jogh.org/2023/jogh-13-05003/>
23. To MM, Nguyen TQN, Phi DL, Khuc VL, Le NQ, Dang KL, et al. Burden of neonatal pneumonia and risk factors for severe disease in low – and middle – income country. Infez Med. 2025;33(4):435–44. <http://dx.doi.org/10.53854/liim-3304-8>
24. Wang, K.C.W., James, A.L., Donovan, G.M. and Noble PB. Prenatal Origins of Obstructive Airway Disease: Starting on the Wrong Trajectory? Comprehensive Physiology. Am Physiol Soc. 2024;14(5):5729–62. <https://doi.org/10.1002/j.2040-4603.2024.tb00804.x>
25. Ma Y, Fan S, Xi JS. Recent updates regarding the management and treatment of pneumonia in pediatric patients: a comprehensive review. Infection. 2025;53(6):2341–59. <https://doi.org/10.1007/s15010-025-02605-w>
26. Pike K, Pillow JJ, Lucas JS. Long term respiratory consequences of intrauterine growth restriction. Semin Fetal Neonatal Med. 2012;17(2):92–8. <https://doi.org/10.1016/j.siny.2012.01.003>
27. Frontera W, Spicer CM, Applegate A. Health Conditions and Impairments Associated with Low Birth Weight and Their Functional Implications - Low Birth Weight Babies and Disability. Low Birth Weight Babies and Disability. 2024. 1–246 p. <https://www.ncbi.nlm.nih.gov/books/NBK605571/>
28. Mwape RK, Barday M Al, Van Der Zalm MM, Verhagen LM. Overview of mucosal immunity and respiratory infections in children: A focus on Africa. Curr Opin Pediatr. 2025;37(2):137–44. <https://doi:10.1097/MOP.0000000000001438>
29. Has EMM, Efendi F, Wahyuni SD, Lailiah N, Mahendra RAP. Predictors of Survival in Under-Five Children with Low Birth Weight: A Population-Based Study in Indonesia. Nurs Reports. 2025;15(7):1–14. <https://doi:10.3390/nursrep15070238>
30. Widoyo R. Measles immunization and Vitamin A for prevention of pneumonia in Indonesia. Kesmas. 2016;11(1):46–50. <https://doi:10.21109/kesmas.v11i1.841>
31. Sidabutar E, Ansariad, Wahiduddin, Bustan N, Stang, Birawida AB. Analysis of risk factor for pneumonia in children less than five years in Makassar. J Educ Health Promot. 2024;13(1):1–6. https://doi:10.4103/jehp.jehp_727_23
32. Islam MZ, Chowdhury MRK, Kader M, Billah B, Islam MS, Rashid M. Determinants of low birth weight and its effect on childhood health and nutritional outcomes in Bangladesh. J Heal Popul Nutr. 2024;43(1):1–11. <https://doi:10.1186/s41043-024-00565-9>
33. Safiri S, Mahmoodpoor A, Kolahi AA, Nejadghaderi SA, Sullman MJM, Mansournia MA, et al. Global burden of lower respiratory infections during the last three decades. Front Public Heal. 2023;10. <https://doi:10.3389/fpubh.2022.1028525>
34. Sukmawati WD. The Relationship Between Low Birth Weight With Pneumonia Toddlers in West Java. J Berk Epidemiol. 2019;7(3):225. <https://doi:10.20473/jbe.V7I32019.225-233>
35. Lutpiatina L, Dwiyantri RD, Insana A. The Role of Biological and Environmental Factors in Infant Pneumonia : Findings from the 2023 Indonesian Health Survey. Trop Heal MedicalResearch. 2026;8(1):37–45.

- <http://www.tropicalhealthandmedicalresearch.com/index.php/JAK/article/view/150>
36. Vakalopoulos A, Dharmage SC, Dharmaratne S, Jayasinghe P, Lall O, Ambrose I, et al. Household air pollution from biomass fuel for cooking and adverse fetal growth outcomes in rural Sri Lanka. *Int J Environ Res Public Health*. 2021;18(4):1–11. <https://doi:10.3390/ijerph18041878>
 37. Mortimer K, Lesosky M, Semple S, Malava J, Katundu C, Crampin A, et al. Pneumonia and Exposure to Household Air Pollution in Children Under the Age of 5 Years in Rural Malawi: Findings From the Cooking and Pneumonia Study. *Chest*. 2020;158(2):501–11. <https://doi:10.1016/j.chest.2020.03.064>
 38. Akbar H, Paundanan M, Reskiaddin LO, Studi P, Kesehatan I, Jambi U. The Relationship Between the Physical Home Environment and the Incidence of Pneumonia Among Under-Five Children in the Working Area of Plumbon Community Health Center. *J Kesmas Jambi*. 2021;5(2):1–8. <https://doi:10.22437/jkmj.v5i2.14306>
 39. Kinney PL, Asante KP, Lee AG, Ae-Ngibise KA, Burkart K, Boamah-Kaali E, et al. Prenatal and Postnatal Household Air Pollution Exposures and Pneumonia Risk: Evidence From the Ghana Randomized Air Pollution and Health Study. *Chest*. 2021;160(5):1634–44. <https://doi:10.1016/j.chest.2021.06.080>
 40. Mccracken JP, Mccollum ED, Steenland K, Nicolaou L, Kirby MA, Grajeda LM, et al. Exposure to Household Air Pollution From Biomass Cooking and Severe Pneumonia in Infants. *JAMA Netw Open*. 2025;8(10). <https://doi:10.1001/jamanetworkopen.2025.38721>