

## Evaluation of Risk Factors for Morbidity and Mortality in Children Aged 1 Month to 6 Years Presenting with Lower Respiratory Tract Infection at a Tertiary Care Referral Hospital

### Authors:

Anjali Kumari<sup>1</sup>, Annpurna Adarsh<sup>1</sup>, Amit Kumar<sup>2</sup>, Rizwan Haider<sup>3</sup>, Shiwali Singh<sup>1</sup>, Yogesh Chandra<sup>1</sup>, Farhan Abdul Hai<sup>1</sup>, Anuj Kumar<sup>1</sup>, Abhishek Kumar<sup>1</sup>

<sup>1</sup>Junior Resident (Academic), Department of Pediatrics, Darbhanga Medical College & Hospital, Laheriasarai, Darbhanga, Bihar- 846003, India.

<sup>2</sup>Assistant Professor, Department of Pediatrics, Darbhanga Medical College & Hospital, Laheriasarai, Darbhanga, Bihar- 846003, India.

<sup>3</sup>Professor & H.O.D., Department of Pediatrics, Darbhanga Medical College & Hospital, Laheriasarai, Darbhanga, Bihar- 846003, India.

### \*Corresponding Author:

Dr. Annpurna Adarsh, Junior Resident (Academic), Department of Pediatrics, Darbhanga Medical College & Hospital, Laheriasarai, Darbhanga, Bihar- 846003, India.

DOI: <https://doi.org/10.5281/zenodo.22907799>

Received: 25 August 2026, Revised: 10 September, Accepted: 20 September 2026, Online First: 03 October 2026

### ABSTRACT

**Background:** Lower respiratory tract infections (LRTI) remain a leading cause of morbidity and mortality in children under six years of age, particularly in resource-limited settings. Identifying modifiable risk factors is essential for targeted prevention and risk stratification. **Methods:** This hospital-based observational study enrolled 100 children aged 1 month to 6 years admitted with LRTI at a tertiary care referral hospital. Demographic, socioeconomic, maternal, nutritional, clinical, laboratory, and environmental variables were recorded. Chi-square and Fisher exact tests, correlation analysis, and multivariable logistic regression were performed using SPSS version 25.0;  $p < 0.05$  was considered statistically significant. **Results:** The mean age was  $20.88 \pm 17.93$  months and 69% were male. Severe pneumonia was the most common diagnosis (38%). Malnutrition was frequent (72% underweight or severely underweight) and case fatality rose from 3.57% in normal children to 27.50% in severely underweight children. Unimmunized children had the highest mortality (32.56%). Non-survivors had lower hemoglobin ( $9.50 \pm 1.35$  g/dL) than survivors ( $11.03 \pm 1.41$  g/dL). Elevated total leukocyte count and C-reactive protein, need for CPAP or ventilation (OR 4.40), ICU admission (OR 4.49), and overcrowding (OR 3.23) predicted poor outcome, whereas exclusive breastfeeding was protective (OR 0.23). The logistic model showed excellent discrimination (AUC-ROC 0.924). **Conclusion:** Malnutrition, incomplete immunization, anemia, hypoxemia, and adverse environmental exposures strongly influence outcomes in pediatric LRTI. Early identification and correction of these factors, together with immunization and breastfeeding promotion, may reduce mortality.

**Keywords:** Lower respiratory tract infection; children; risk factors; malnutrition; immunization; mortality; odds ratio; logistic regression

### 1. INTRODUCTION

Acute lower respiratory tract infections (LRTI), encompassing bronchiolitis, pneumonia, and severe pneumonia, continue to impose a substantial burden of disease and death on children younger than six years, and the toll is heaviest in low- and middle-income countries [1,2,7]. Despite steady gains in immunization coverage and nutrition, pneumonia alone remains among the leading infectious causes of childhood

mortality worldwide [1,2], and children admitted to referral hospitals frequently arrive with advanced disease and multiple overlapping vulnerabilities.

Beyond the infecting pathogen itself, the outcome of an episode of LRTI is shaped by a constellation of host, household, and healthcare factors: age, sex, birth weight, breastfeeding practices, nutritional status, maternal education, socioeconomic position, immunization, indoor air pollution, passive smoking, and overcrowding [3,4,7]. Understanding which of

these factors independently predicts death or residual morbidity allows clinicians to triage high-risk children and allows public health programs to direct preventive interventions where they will yield the greatest benefit. A number of prior studies have examined individual risk domains, but relatively few have assessed demographic, socioeconomic, nutritional, laboratory, and environmental determinants simultaneously within a single admitted cohort in the North Indian setting [39,43].

The present study was therefore undertaken to evaluate the risk factors for morbidity and mortality in children aged 1 month to 6 years presenting with LRTI to a tertiary care referral hospital, and to construct a multivariable model of poor outcome using routinely available clinical and laboratory parameters.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

This was a hospital-based observational study conducted in the Department of Pediatrics at Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India, during the academic session 2023–2026.

2.2 Study Population

One hundred children aged 1 month to 6 years admitted with a clinical diagnosis of LRTI (bronchiolitis, pneumonia, or severe pneumonia as per WHO-based clinical criteria) were enrolled consecutively. Children with known chronic lung disease, congenital heart disease, immunodeficiency, or obvious alternative diagnoses were excluded.

2.3 Data Collection

A structured proforma recorded demographic details (age, sex), socioeconomic and maternal variables

(maternal education, socioeconomic status, family type, overcrowding), birth and feeding history (birth weight, prematurity, exclusive breastfeeding and its duration), immunization status, environmental exposures (indoor air pollution, passive smoking, cooking fuel), presenting clinical features, and laboratory investigations (hemoglobin, total leukocyte count [TLC], C-reactive protein [CRP], oxygen saturation). Treatment details (oxygen, antibiotics, CPAP or ventilation, ICU admission) and outcomes (recovered, discharged with morbidity, death) were documented along with the duration of hospital stay.

2.4 Definitions

Nutritional status was classified as normal, underweight, or severely underweight using age-appropriate weight-for-age criteria. Hypoxemia was defined by pulse-oximetric oxygen saturation below 90%. Poor outcome comprised death or discharge with residual morbidity.

2.5 Statistical Analysis

Data were analyzed with SPSS version 25.0. Categorical variables were compared with the chi-square test or Fisher exact test, and continuous variables with t-tests or ANOVA as appropriate. Pearson correlation was used to explore associations between continuous clinical parameters. Multivariable logistic regression identified independent predictors of poor outcome, and model discrimination was quantified by the area under the receiver operating characteristic curve (AUC-ROC). A two-sided p-value below 0.05 was considered statistically significant.

3. RESULTS

3.1 Demographic Profile

The cohort comprised 100 children with a mean age of 20.88±17.93 months (median 11.5, range 2–62 months). Infants aged 3–12 months formed the largest group (51%), and boys outnumbered girls by 2.23:1.

Table 1: Age distribution of the study cohort (N=100)

| Age group    | Frequency (n) | Percentage (%) |
|--------------|---------------|----------------|
| 1–2 months   | 1             | 1.0            |
| 3–12 months  | 51            | 51.0           |
| 13–24 months | 16            | 16.0           |
| 25–36 months | 8             | 8.0            |
| 37–48 months | 12            | 12.0           |
| 49–72 months | 12            | 12.0           |
| Total        | 100           | 100.0          |

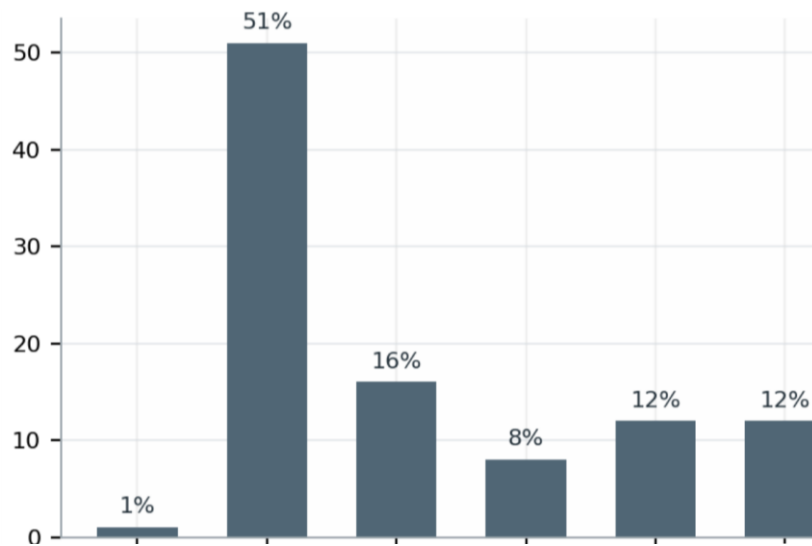


**Figure 1: Age distribution of the study cohort**

**Table 2: Sex distribution (N=100)**

| Sex    | Frequency (n) | Percentage (%) |
|--------|---------------|----------------|
| Male   | 69            | 69.0           |
| Female | 31            | 31.0           |
| Total  | 100           | 100.0          |

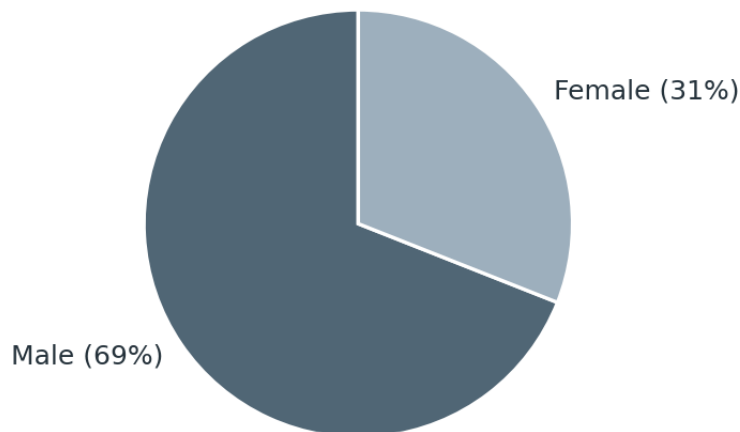


**Figure 2: Sex distribution of the study cohort**

### 3.2 Socioeconomic, Maternal, and Birth Characteristics

A substantial proportion of mothers were illiterate (36%) and most families belonged to lower socioeconomic strata (44% lower, 36% upper-lower). Only one-third of infants had been exclusively breastfed, and 56% had low birth weight [40-42].

**Table 3: Socioeconomic, maternal, and birth characteristics (N=100)**

| Variable                | Category         | Frequency (n) | Percentage (%) |
|-------------------------|------------------|---------------|----------------|
| Maternal education      | Illiterate       | 36            | 36.0           |
|                         | Primary          | 26            | 26.0           |
|                         | Secondary        | 22            | 22.0           |
|                         | Graduate         | 16            | 16.0           |
| Socioeconomic status    | Lower            | 44            | 44.0           |
|                         | Upper-lower      | 36            | 36.0           |
|                         | Lower-middle     | 17            | 17.0           |
|                         | Upper-middle     | 3             | 3.0            |
| Exclusive breastfeeding | Yes              | 33            | 33.0           |
|                         | No               | 67            | 67.0           |
| Birth weight            | Low birth weight | 56            | 56.0           |
|                         | Normal           | 44            | 44.0           |

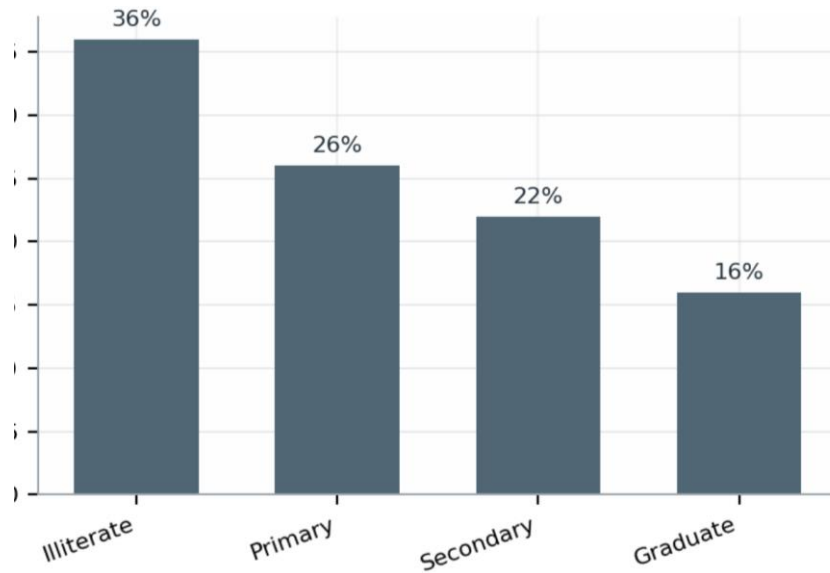


**Figure 3: Maternal educational status**

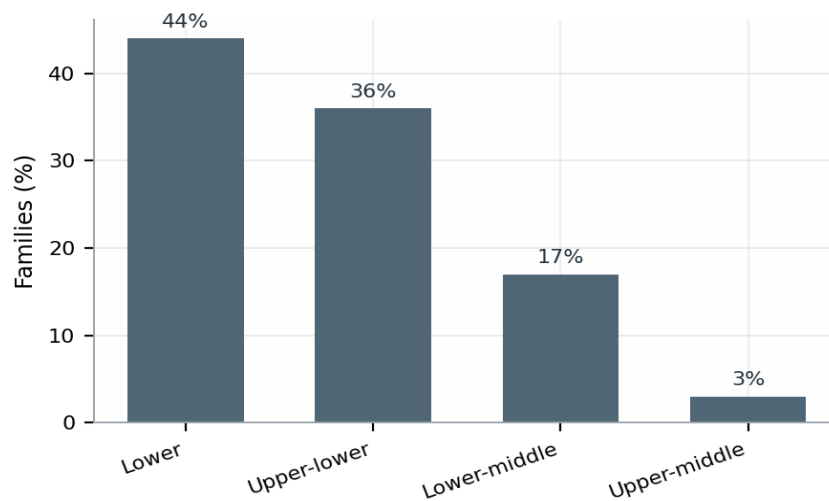


**Figure 4: Socioeconomic status distribution**

### 3.3 Clinical and Laboratory Parameters

At presentation the mean oxygen saturation was  $87.51 \pm 9.34\%$ , mean hemoglobin  $10.88 \pm 1.48$  g/dL, mean TLC  $13,507.68 \pm 5,995.30$  cells/ $\mu$ L, and mean CRP  $30.31 \pm 17.65$  mg/L. The mean duration of symptoms before admission was  $6.16 \pm 2.30$  days, and the mean hospital stay was  $8.08 \pm 3.88$  days.

**Table 4: Clinical and laboratory parameters of the cohort (N=100)**

| Parameter                             | Mean $\pm$ SD            | Median | Range        |
|---------------------------------------|--------------------------|--------|--------------|
| Age (months)                          | $20.88 \pm 17.93$        | 11.5   | 2–62         |
| Weight (kg)                           | $8.69 \pm 3.52$          | 7.6    | 3.8–18.7     |
| Breastfeeding duration (months)       | $3.79 \pm 3.90$          | 3.0    | 0–15         |
| Duration of symptoms (days)           | $6.16 \pm 2.30$          | 6.5    | 1–10         |
| Oxygen saturation (%)                 | $87.51 \pm 9.34$         | 88.5   | 7–100        |
| Hemoglobin (g/dL)                     | $10.88 \pm 1.48$         | 11.1   | 7.0–13.8     |
| TLC (cells/ $\mu$ L)                  | $13,507.68 \pm 5,995.30$ | 12,807 | 1,879–29,870 |
| CRP (mg/L)                            | $30.31 \pm 17.65$        | 29.9   | 3.3–82.6     |
| Duration of antibiotic therapy (days) | $5.41 \pm 4.56$          | 7.0    | 0–14         |
| Duration of hospital stay (days)      | $8.08 \pm 3.88$          | 8.0    | 1–16         |

As reported in the source thesis, the minimum oxygen saturation value of 7% appears to be a data-entry artifact.

### 3.4 Nutritional Status and Case Fatality

Malnutrition was highly prevalent: 32% were underweight and 40% severely underweight. Case fatality rose steeply across nutritional categories, from 3.57% in normal children to 18.75% in underweight and 27.50% in severely underweight children (chi-square 6.407,  $p=0.041$ ).

**Table 5: Nutritional status and associated case fatality (N=100)**

| Nutritional status   | n   | %     | Case fatality (%) |
|----------------------|-----|-------|-------------------|
| Normal               | 28  | 28.0  | 3.57              |
| Underweight          | 32  | 32.0  | 18.75             |
| Severely underweight | 40  | 40.0  | 27.50             |
| Total                | 100 | 100.0 |                   |

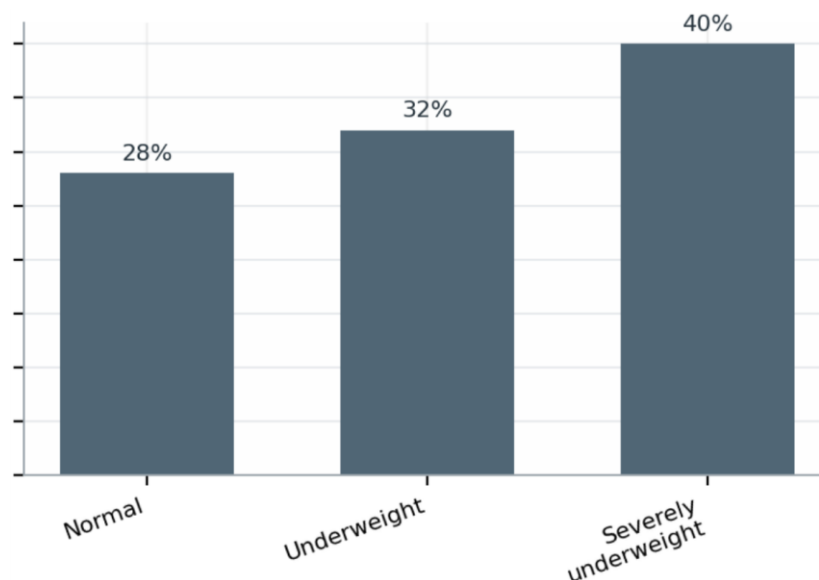


**Figure 5: Nutritional status of the study cohort**

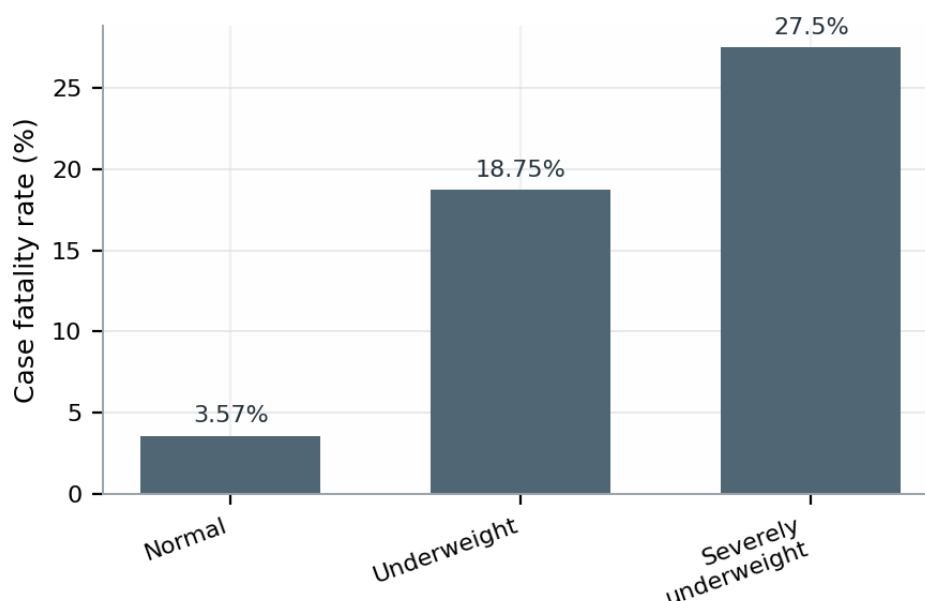


**Figure 6: Case fatality rate by nutritional status**

### 3.5 Clinical Diagnosis and Outcome

Severe pneumonia was the most frequent diagnosis (38%), followed by pneumonia (32%) and bronchiolitis (30%). Diagnosis was significantly associated with outcome (chi-square 13.787,  $p=0.008$ ): no deaths occurred among children with bronchiolitis, whereas case fatality was highest in severe pneumonia (23.68%) and pneumonia (15.62%).

**Table 6: Clinical diagnosis distribution and outcome (N=100)**

| Clinical diagnosis | N   | Case fatality (%) |
|--------------------|-----|-------------------|
| Bronchiolitis      | 30  | 0.00              |
| Pneumonia          | 32  | 15.62             |
| Severe pneumonia   | 38  | 23.68             |
| Total              | 100 |                   |

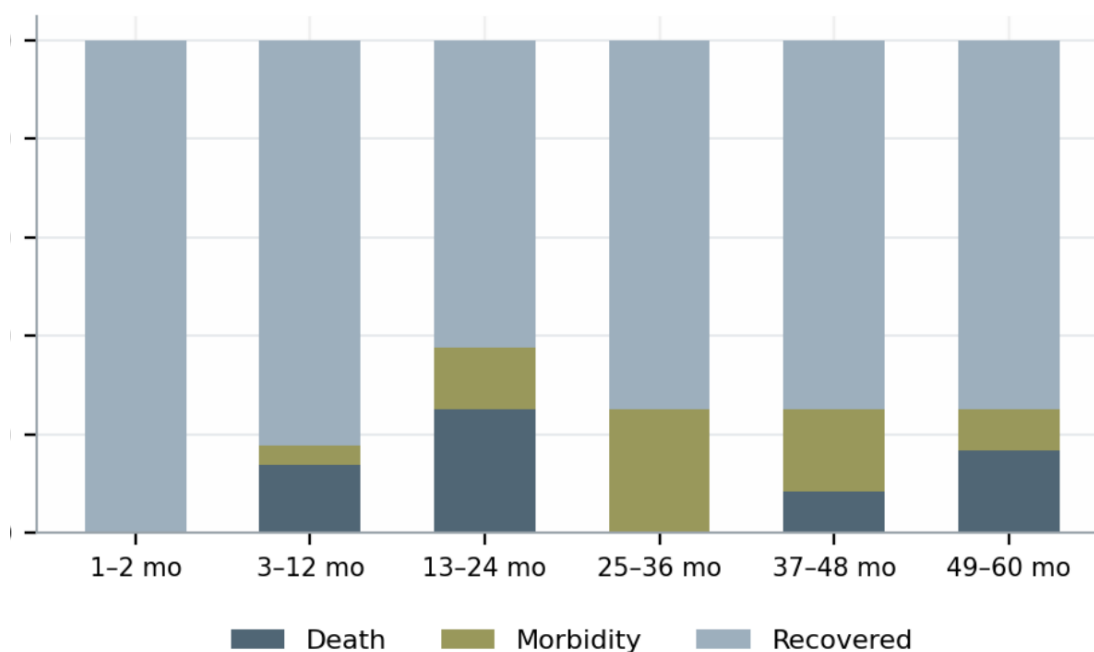
### 3.6 Age, Nutrition, and Immunization in Relation to Outcome

The highest mortality proportion (25%) occurred in the 13–24-month age group, but the association between age group and outcome did not reach statistical significance (chi-square 8.528,  $p=0.577$ ). Mortality showed a graded rise with worsening nutritional status, although this was not statistically significant (chi-square 7.483,  $p=0.113$ ). In contrast, immunization status was strongly associated with outcome (chi-square 23.12,  $p<0.001$ ): unimmunized children had the highest mortality (32.56%) and the lowest recovery (62.79%), while no death occurred among fully immunized children.

**Table 7: Age group versus outcome (percentage within age group)**

| Age group    | Death (%) | Morbidity (%) | Recovered (%) |
|--------------|-----------|---------------|---------------|
| 1–2 months   | 0.00      | 0.00          | 100.00        |
| 3–12 months  | 13.73     | 3.92          | 82.35         |
| 13–24 months | 25.00     | 12.50         | 62.50         |
| 25–36 months | 0.00      | 25.00         | 75.00         |
| 37–48 months | 8.33      | 16.67         | 75.00         |
| 49–60 months | 16.67     | 8.33          | 75.00         |

Chi-square 8.528,  $p = 0.577$ .

**Figure 7: Outcome by age group****Table 8: Nutritional status versus outcome (percentage within group)**

| Nutritional status   | Death (%) |
|----------------------|-----------|
| Normal               | 5.26      |
| Underweight          | 14.81     |
| Severely underweight | 22.86     |

Chi-square 7.483,  $p = 0.113$ .

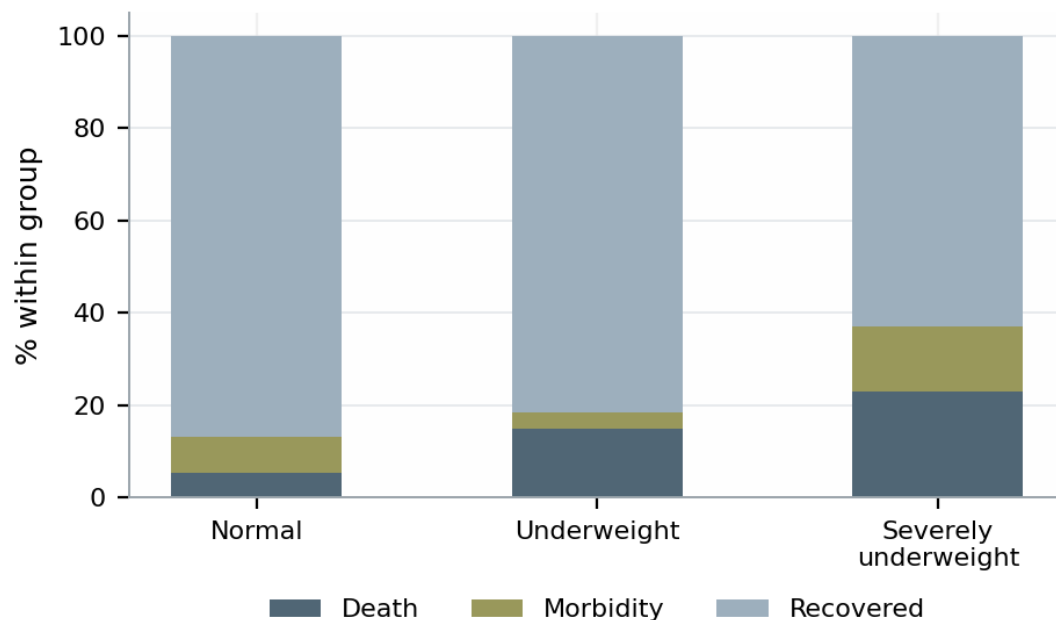


**Figure 8: Outcome by nutritional status**

**Table 9: Immunization status by clinical outcome**

| Immunization status | Recovered (n) | Recovered (%) |
|---------------------|---------------|---------------|
| Complete            | 22            | 81.48         |
| Partial             | 28            | 93.33         |
| Unimmunized         | 27            | 62.79         |

Chi-square 23.12,  $p < 0.001$ .

### 3.7 Risk Factors for Poor Outcome

In bivariate analysis, exclusive breastfeeding was strongly protective (OR 0.23, 95% CI 0.06–0.86,  $p=0.039$ ), whereas overcrowding (OR 3.23, 95% CI 1.15–9.06,  $p=0.040$ ), need for CPAP or ventilation (OR 4.40, 95% CI 1.64–11.81,  $p=0.005$ ), and ICU admission (OR 4.49, 95% CI 1.23–16.42,  $p=0.030$ ) were associated with poor outcome [33,36].

**Table 10: Association between risk factors and poor outcome**

| Risk factor               | Poor outcome (Yes) | Poor outcome (No) | OR   | 95% CI     | p-value |
|---------------------------|--------------------|-------------------|------|------------|---------|
| Prematurity history       | 14/56              | 9/44              | 1.30 | 0.50–3.35  | 0.7666  |
| Exclusive breastfeeding   | 3/33               | 20/67             | 0.23 | 0.06–0.86  | 0.0387  |
| Overcrowding              | 17/53              | 6/47              | 3.23 | 1.15–9.06  | 0.0402  |
| Indoor air pollution      | 14/48              | 9/52              | 1.97 | 0.76–5.09  | 0.2420  |
| Passive smoking           | 10/47              | 13/53             | 0.83 | 0.33–2.12  | 0.8827  |
| Previous LRTI history     | 12/46              | 11/54             | 1.38 | 0.54–3.51  | 0.6609  |
| Co-morbid malnutrition    | 10/55              | 13/45             | 0.55 | 0.21–1.40  | 0.3045  |
| Fever                     | 19/73              | 4/27              | 2.02 | 0.62–6.61  | 0.3601  |
| Need for CPAP/ventilation | 15/38              | 8/62              | 4.40 | 1.64–11.81 | 0.0048  |
| ICU admission             | 20/66              | 3/34              | 4.49 | 1.23–16.42 | 0.0302  |

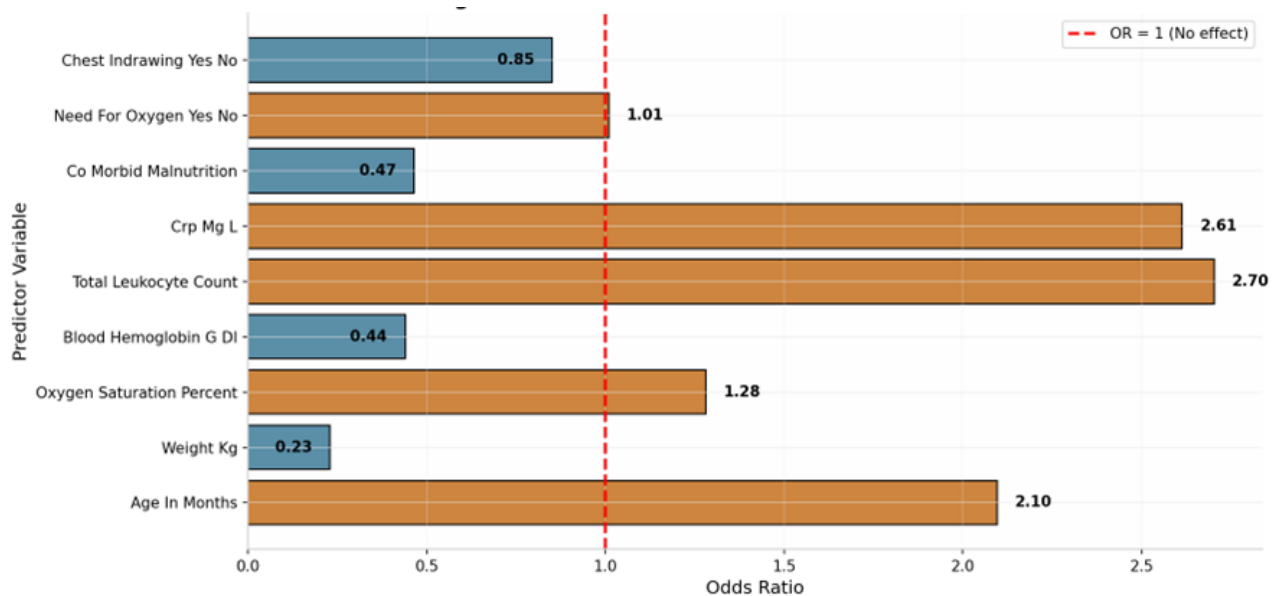


**Figure 9: Odds ratios for risk factors of poor outcome, log scale**

### 3.8 Laboratory Markers Across Outcomes and Diagnoses

Mean hemoglobin was significantly lower in children who died ( $9.50 \pm 1.35$  g/dL) than in those who recovered ( $11.03 \pm 1.41$  g/dL;  $t=3.230$ ,  $p=0.002$ ). TLC differed significantly across diagnoses ( $F=19.076$ ,  $p<0.0001$ ), with severe pneumonia showing substantially higher counts than bronchiolitis or pneumonia.

**Table 11: Hemoglobin levels by clinical outcome**

| Clinical outcome          | Mean $\pm$ SD (g/dL) |
|---------------------------|----------------------|
| Recovered                 | $11.03 \pm 1.41$     |
| Discharged with morbidity | $11.80 \pm 1.00$     |
| Death                     | $9.50 \pm 1.35$      |

**Table 12: Total leukocyte count by clinical diagnosis**

| Clinical diagnosis | N  | Mean $\pm$ SD (cells/ $\mu$ L) | Median | Range        |
|--------------------|----|--------------------------------|--------|--------------|
| Bronchiolitis      | 30 | $10,515 \pm 2,790$             | 10,164 | 6,266–16,002 |
| Pneumonia          | 32 | $11,545 \pm 5,398$             | 10,831 | 4,134–29,870 |
| Severe pneumonia   | 38 | $17,523 \pm 6,206$             | 16,239 | 1,879–29,780 |

ANOVA  $F = 19.076$ ,  $p < 0.0001$ .

### 3.9 Correlation and Regression Analysis

Age correlated strongly and positively with weight ( $r=0.788$ ,  $p<0.001$ ). Oxygen saturation correlated negatively with TLC ( $r=-0.403$ ,  $p<0.001$ ), while CRP correlated positively with TLC ( $r=0.495$ ) and with hospital stay ( $r=0.412$ ). In multivariable logistic regression, elevated TLC (OR 2.703), elevated CRP (OR 2.614), and increasing age (OR 2.096) predicted poor outcome, whereas higher weight (OR 0.229) and higher hemoglobin (OR 0.439) were protective; the model achieved an AUC-ROC of 0.924.

**Table 13: Correlation matrix of clinical parameters**

| Variable 1            | Variable 2           | r-value | p-value  | Interpretation    |
|-----------------------|----------------------|---------|----------|-------------------|
| Age (months)          | Weight (kg)          | 0.788   | $<0.001$ | Strong positive   |
| Age (months)          | CRP (mg/L)           | 0.312   | 0.0016   | Moderate positive |
| Weight (kg)           | Hospital stay (days) | 0.323   | 0.0010   | Moderate positive |
| Oxygen saturation (%) | TLC                  | -0.403  | $<0.001$ | Moderate negative |
| TLC                   | CRP (mg/L)           | 0.495   | $<0.001$ | Moderate positive |
| CRP (mg/L)            | Hospital stay (days) | 0.412   | $<0.001$ | Moderate positive |

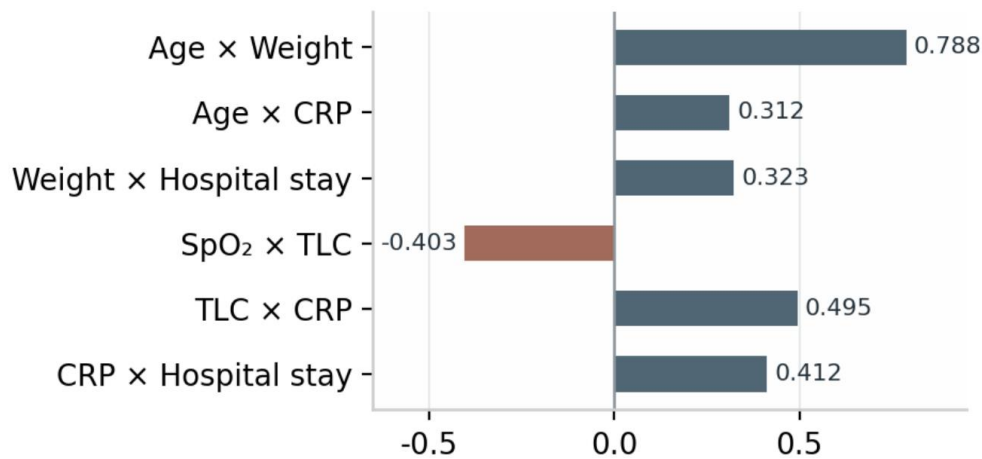


**Figure 10: Correlation coefficients between clinical parameters**

**Table 14: Multivariable logistic regression for poor outcome**

| Variable               | Coefficient |
|------------------------|-------------|
| Age (months)           | 0.740       |
| Weight (kg)            | -1.473      |
| Oxygen saturation (%)  | 0.248       |
| Hemoglobin (g/dL)      | -0.824      |
| Total leukocyte count  | 0.994       |
| CRP (mg/L)             | 0.961       |
| Co-morbid malnutrition | -0.767      |
| Chest indrawing        | -0.161      |

Model discrimination AUC-ROC = 0.924.

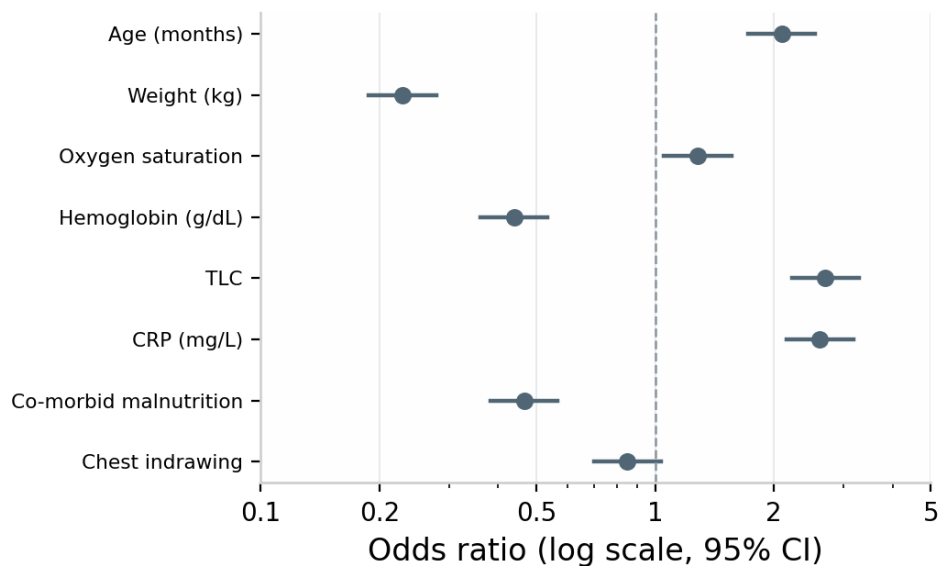


**Figure 11: Odds ratios for predictors of poor outcome from logistic regression, log scale**

### 3.10 Environmental Exposures and Poor Outcome

Indoor air pollution (29.2% vs 17.3% poor outcome; chi-square 6.474,  $p=0.039$ ) and passive smoking (28.0% vs 12.0%; chi-square 4.000,  $p=0.0455$ ) were significantly associated with poor outcome, while overcrowding showed the largest effect size (32.1% vs 12.8%) but narrowly missed significance (chi-square 5.333,  $p=0.0695$ ).

**Table 15: Environmental factors versus poor outcome**

| Risk factor          | Exposed, poor outcome (%) | Not exposed, poor outcome (%) | Chi-square | p-value |
|----------------------|---------------------------|-------------------------------|------------|---------|
| Indoor air pollution | 29.2                      | 17.3                          | 6.474      | 0.039   |
| Passive smoking      | 28.0                      | 12.0                          | 4.000      | 0.0455  |
| Overcrowding         | 32.1                      | 12.8                          | 5.333      | 0.0695  |

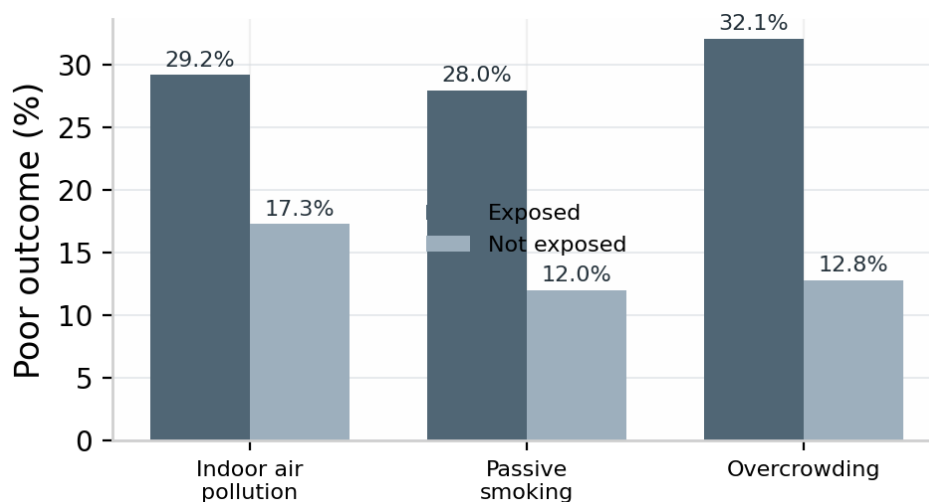


**Figure 12: Environmental exposures and poor outcome**

## 4. DISCUSSION

This hospital-based analysis examined a broad set of demographic, socioeconomic, nutritional, clinical, laboratory, and environmental determinants of outcome in children aged 1 month to 6 years admitted with LRTI at a North Indian tertiary referral center. Several findings carry direct implications for triage and prevention.

### 4.1 Age and Sex Pattern

The concentration of cases in the 3–12-month age group (51%) and the overall mean age of 20.9 months mirror the well-known vulnerability of infants, in whom waning maternal antibody, immature adaptive immunity, and narrow airways converge [9–11]. The male predominance (69%, M:F 2.23:1) is consistent with systematic evidence of higher LRTI morbidity and mortality in boys across diverse populations [12], and supports the inclusion of young age and male sex in clinical risk awareness.

### 4.2 Socioeconomic and Maternal Factors

The socioeconomic profile of the cohort was striking: 36% of mothers were illiterate, 80% of families belonged to lower or upper-lower strata, only 33% of infants were exclusively breastfed, and 56% had low birth weight. These figures delineate the social gradient within which severe LRTI flourishes. Maternal education and household economic position shape feeding practices, health-seeking behavior, and domestic environment, and prospective cohort evidence confirms maternal education as an independent determinant of infant LRTI risk [13–15].

### 4.3 Nutrition and Outcome

Malnutrition was the dominant comorbidity: 72% of children were underweight or severely underweight, and case fatality climbed from 3.57% to 27.50% across nutritional grades, in keeping with large pooled analyses showing sharply higher pneumonia mortality among malnourished children [5,8,18]. Although the nutrition-outcome cross-tabulation in this sample did not reach statistical significance, the graded direction

of effect, together with the regression estimate, reinforces nutrition as a central modifiable determinant rather than a mere association.

### 4.4 Diagnosis, Immunization, and Severity Markers

Severe pneumonia accounted for the largest share of admissions (38%) and of deaths (case fatality 23.68%), whereas bronchiolitis had no fatalities, a severity gradient consistent with intensive-care series [19–21]. Immunization status showed the strongest categorical association with outcome ( $p < 0.001$ ): no fully immunized child died, while unimmunized children carried a mortality of 32.56%. Laboratory markers tracked severity in a biologically coherent manner: hemoglobin was lower in non-survivors [22,23], TLC was highest in severe pneumonia, and hypoxemia correlated with leukocytosis, supporting the routine use of pulse oximetry and simple blood indices for severity stratification in resource-limited settings [24–26,34–36].

### 4.5 Predictive Model

The multivariable model combining routinely available variables (age, weight, oxygen saturation, hemoglobin, TLC, CRP) discriminated strongly between favorable and poor outcomes (AUC-ROC 0.924). Independent predictors of poor outcome were elevated TLC and CRP and increasing age, while higher weight and hemoglobin were protective. Exclusive breastfeeding reduced the odds of poor outcome by about 77% (OR 0.23), echoing case-control evidence that sustained exclusive breastfeeding lowers both the incidence and the severity of pneumonia in infancy [6,16,17,32].

### 4.6 Environmental Exposures

Indoor air pollution and passive smoking were each significantly associated with poor outcome, and overcrowding, despite narrowly missing significance in the percentage comparison, carried one of the largest adjusted effect sizes (OR 3.23). Domestic biomass combustion and crowded, poorly ventilated housing are well-documented drivers of childhood respiratory disease in South Asia [27–31], and the

present findings reinforce that environmental remediation belongs alongside medical care in any serious LRTI-control strategy.

#### 4.7 Strengths and Limitations

Strengths include the simultaneous evaluation of demographic, socioeconomic, nutritional, laboratory, and environmental domains; the use of complementary analytic methods (chi-square tests, correlation, and multivariable logistic regression); and the strong discrimination of the final model. Limitations include the single-center design, modest sample size, reliance on reported household exposures rather than direct measurement, limited granularity in vaccination and nutritional assessment, hospital-based (retrospective, record-dependent) data collection, and the absence of post-discharge follow-up, which precludes assessment of recurrent infection and long-term sequelae.

#### 5. CONCLUSION

Among children aged 1 month to 6 years admitted with LRTI, adverse outcomes clustered in those who were malnourished, unimmunized, anemic, hypoxemic, of low birth weight, and exposed to indoor air pollution, passive smoking, and overcrowding, while exclusive breastfeeding conferred substantial protection. Severe pneumonia carried the highest case fatality [37,38]. A logistic model built on routinely available clinical and laboratory parameters identified elevated TLC and CRP, increasing age, lower weight, and lower hemoglobin as independent predictors of poor outcome, with excellent discrimination (AUC-ROC 0.924). Early risk stratification using these simple parameters, together with intensified immunization, breastfeeding promotion, nutritional rehabilitation, anemia correction, and reduction of indoor environmental exposures, offers a practical pathway to reducing LRTI morbidity and mortality in similar settings.

#### Ethics approval and consent to participate

The study was approved by the Institutional Ethics Committee of Darbhanga Medical College and Hospital, Laheriasarai. Written informed consent was obtained from the parents or legal guardians of all participants prior to enrolment.

#### Funding

No external funding was received for this study.

#### Competing interests

The authors declare no competing interests.

#### Authors' contributions

All authors contributed to the conception and design of the study, data collection, analysis and interpretation of the results, and preparation of the manuscript. All authors critically reviewed the manuscript, approved

the final version, and agreed to be accountable for all aspects of the work.

#### Acknowledgement

The authors thank the staff of the Special Newborn Care Unit, Department of Paediatrics, Darbhanga Medical College and Hospital, and the parents who consented to their infants' participation.

#### AI Use Disclosure

The authors declare that no generative artificial intelligence tools were used to generate or substantially modify the scientific content of this manuscript.

#### REFERENCES

1. Wang X, Li Y, Deloria-Knoll M, Madhi SA, Cohen C, Arguelles VL, et al. Global burden of acute lower respiratory infection associated with human parainfluenza virus in children younger than 5 years for 2018: a systematic review and meta-analysis. *Lancet Glob Health*. 2021;9(8):e1077-e87.
2. Xing X, Tang S, Wang W, Xiong H, Zhang T, Wang W, et al. Trends in mortality from lower respiratory infections in children under 14 years, 1990–2019: an analysis of the Global Burden of Disease Study 2019. *Heliyon*. 2024;10(21).
3. Rana J, Uddin J, Peltier R, Oulhote Y. Associations between indoor air pollution and acute respiratory infections among under-five children in Afghanistan: do SES and sex matter? *Int J Environ Res Public Health*. 2019;16(16):2910.
4. 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 Health*. 2024;57(5):461.
5. Kirolos A, Blacow RM, Parajuli A, Welton NJ, Khanna A, Allen SJ, et al. The impact of childhood malnutrition on mortality from pneumonia: a systematic review and network meta-analysis. *BMJ Glob Health*. 2021;6(11).
6. Hossain S, Mihrshahi S. Exclusive breastfeeding and childhood morbidity: a narrative review. *Int J Environ Res Public Health*. 2022;19(22):14804.
7. Sonogo M, Pellegrin MC, Becker G, Lazzerini M. Risk factors for mortality from acute lower respiratory infections in children under five years of age in low and middle-income countries: a systematic review and meta-analysis. *PLoS One*. 2015;10(1):e0116380.

8. Srivastava AD, Awasthi S, Jauhari S. Prevalence of persistent pneumonia among severe pneumonia and nutritional status as its associated risk factor: a prospective observational study among under-five children. *J Family Med Prim Care*. 2024;13(5):1911-6.
9. Sitthikarnkha P, Uppala R, Niamsanit S, Sutra S, Thepsuthammarat K, Techasatian L, et al. Epidemiology of acute lower respiratory tract infection hospitalizations in Thai children: a 5-year national data analysis. *Influenza Other Respir Viruses*. 2022;16(1):142-50.
10. Liu P, Xu M, He L, Su L, Wang A, Fu P, et al. Epidemiology of respiratory pathogens in children with lower respiratory tract infections in Shanghai, China, from 2013 to 2015. *Jpn J Infect Dis*. 2018;71(1):39-44.
11. Le Roux DM, Nicol MP, Myer L, Vanker A, Stadler JA, von Delft E, et al. Lower respiratory tract infections in children in a well-vaccinated South African birth cohort: spectrum of disease and risk factors. *Clin Infect Dis*. 2019;69(9):1588-96.
12. Orimadegun AE, Adepoju AA, Myer L. A systematic review and meta-analysis of sex differences in morbidity and mortality of acute lower respiratory tract infections among African children. *J Pediatr Rev*. 2020;8(2):65.
13. MacGinty R, Lesosky M, Barnett W, Nduru PM, Vanker A, Stein DJ, et al. Maternal psychosocial risk factors and lower respiratory tract infection during infancy in a South African birth cohort. *PLoS One*. 2019;14(12):e0226144.
14. Seth S, Ganguly S, Satpathy SK. Risk factors responsible for lower respiratory tract infections in children aged under five: a hospital based study. *Int J Contemp Pediatr*. 2020;7(7):1578.
15. Chinawa A, Chinawa J, Nduagubam O, Chukwu B, Nwokoye I, Amadi O, et al. Clinical profile, severity pattern and socio-demographic risk factors of acute lower respiratory tract infection in children in Enugu, Nigeria. *Curr Respir Med Rev*. 2020;16(2):123-31.
16. Pandolfi E, Gesualdo F, Rizzo C, Carloni E, Villani A, Concato C, et al. Breastfeeding and respiratory infections in the first 6 months of life: a case control study. *Front Pediatr*. 2019;7:152.
17. Vassilopoulou E, Agostoni C, Feketea G, Alberti I, Gianni ML, Milani GP. The role of breastfeeding in acute respiratory infections in infancy. *Pediatr Infect Dis J*. 2024;43(11):1090-9.
18. Gamal Y, Mahmoud AO, Mohamed SA, Mohamed JI, Raheem YFA. Prevalence and impact of malnutrition on outcomes and mortality of under-five years children with pneumonia: a study from Upper Egypt. *Eur J Pediatr*. 2023;182(10):4583-93.
19. Mahant S, Parkin PC, Thavam T, Imsirovic H, Tuna M, Knight B, et al. Rates in bronchiolitis hospitalization, intensive care unit use, mortality, and costs from 2004 to 2018. *JAMA Pediatr*. 2022;176(3):270-9.
20. Ghazaly M, Nadel S. Characteristics of children admitted to intensive care with acute bronchiolitis. *Eur J Pediatr*. 2018;177(6):913-20.
21. Cao L, Ji Z, Zhang P, Wang J. Epidemiology and mortality predictors for severe childhood community-acquired pneumonia in ICUs: a retrospective observational study. *Front Pediatr*. 2023;11:1031423.
22. Shakya H, Singh S, Lakhey A. Anemia as a risk factor for acute lower respiratory tract infection in children below five years of age. *Nepalese Med J*. 2018;1(1):5-8.
23. Jayamanna U, Jayaweera JS. Childhood anemia and risk for acute respiratory infection, gastroenteritis, and urinary tract infection: a systematic review. *J Pediatr Infect Dis*. 2023;18(02):061-70.
24. Florin TA, Ambroggio L, Brokamp C, Zhang Y, Rattan M, Crotty E, et al. Biomarkers and disease severity in children with community-acquired pneumonia. *Pediatrics*. 2020;145(6).
25. Fernandes CD, Arriaga MB, Costa MCM, Costa MHM, Vinhaes CL, et al. Host inflammatory biomarkers of disease severity in pediatric community-acquired pneumonia: a systematic review and meta-analysis. *Open Forum Infect Dis*. 2019.
26. Pervin S, Akhter R, Farzana N, Khanom T. Assessment of inflammatory markers (CBC and CRP) and their impact on severity and recurrence of pneumonia in under-five children. *Sch J App Med Sci*. 2024;10:1391-6.
27. 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.
28. Mohammadi M, Mohammadi P. Indoor air pollution and acute respiratory infection among children: an update biomass smoke. *J Air Pollut Health*. 2018;3(1):49-62.
29. Islam M, Sultana ZZ, Iqbal A, Ali M, Hossain A. Effect of in-house crowding on childhood hospital admissions for acute respiratory infection:

a matched case-control study in Bangladesh. *Int J Infect Dis.* 2021;105:639-45.

30. Gothankar J, Doke P, Dhumale G, Pore P, Lalwani S, Quraishi S, et al. Reported incidence and risk factors of childhood pneumonia in India: a community-based cross-sectional study. *BMC Public Health.* 2018;18(1):1111.

31. Kasundriya SK, Dhaneria M, Mathur A, Pathak A. Incidence and risk factors for severe pneumonia in children hospitalized with pneumonia in Ujjain, India. *Int J Environ Res Public Health.* 2020;17(13):4637.

32. Kang YL, Zheng QX, Chen XQ, Huang YC, Zheng F. Effects of exclusive breastfeeding duration on pneumonia occurrence and course in infants up to 6 months of age: a case-control study. *J Community Health Nurs.* 2024;41(4):256-64.

33. Meliyanti A, Rusmawatinings D, Makrufardi F, Arguni E. Factors associated with mortality in pediatric pneumonia patients supported with mechanical ventilation in developing country. *Heliyon.* 2021;7(5).

34. Rahman AE, Hossain AT, Chisti MJ, Dockrell DH, Nair H, El Arifeen S, et al. Hypoxaemia prevalence and its adverse clinical outcomes among children hospitalised with WHO-defined severe pneumonia in Bangladesh. *J Glob Health.* 2021;11:04053.

35. Rahman AE, Hossain AT, Nair H, Chisti MJ, Dockrell D, El Arifeen S, et al. Prevalence of hypoxaemia in children with pneumonia in low-income and middle-income countries: a systematic review and meta-analysis. *Lancet Glob Health.* 2022;10(3):e348-e59.

36. Dean P, Florin TA. Factors associated with pneumonia severity in children: a systematic review. *J Pediatric Infect Dis Soc.* 2018;7(4):323-34.

37. Goyal JP, Kumar P, Mukherjee A, Das RR, Bhat JI, Ratageri V, et al. Risk factors for the development of pneumonia and severe pneumonia in children. *Indian Pediatr.* 2021;58(11):1036-9.

38. Jakhar SK, Pandey M, Shah D, Ramachandran V, Saha R, Gupta N, et al. Etiology and risk factors determining poor outcome of severe pneumonia in under-five children. *Indian J Pediatr.* 2018;85(1):20-4.

39. Tewary S, De S, Khawash P. Evaluation of risk factors for morbidity and mortality in children aged 1 month-6 years presenting with lower respiratory tract infection to a referral hospital. *Int J Contemp Pediatr.* 2023;10(5):663.

40. Shi T, Vennard S, Mahdy S, Nair H. Risk factors for poor outcome or death in young children with respiratory syncytial virus-associated acute lower respiratory tract infection: a systematic review and meta-analysis. *J Infect Dis.* 2022;226(Suppl 1):S10-S6.

41. 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;13:1620077.

42. Wang Y, Xiang Y, Jin R, Li B, Feng X, Han Q, et al. Risk factors for severe lower respiratory tract infection among children under 5 years of age hospitalized with respiratory syncytial virus. *Eur J Clin Microbiol Infect Dis.* 2025;44(9):2239-51.

43. Sürücü Kara I, Aydin Peker N, Arslan Y, Topal I. Risk factors for lower respiratory tract infection and recurrent lower respiratory tract infection in children. *Van Tıp Dergisi.* 2024;31(1).