

Risk Factors for Community-Acquired Pneumonia in Children under Five in the Post-Pneumococcal Vaccine Era in Lahore, Pakistan: A Case-Control Study

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ABSTRACT

Background And Objective: Childhood pneumonia remains a leading cause of morbidity and mortality, particularly in resource-limited settings such as Pakistan. This study aimed to determine the risk factors influencing the severity of community-acquired pneumonia in children under five years of age in Punjab Province, Pakistan.

Methods: A case-control study was conducted at Mayo Hospital, Lahore, Pakistan, involving 126 children aged 2–59 months, including 63 cases diagnosed with community-acquired pneumonia and 63 controls. Data were collected through structured interviews and medical record reviews covering clinical, environmental, and socio-demographic variables. Logistic regression analysis was performed using SPSS version 26 to identify factors associated with pneumonia severity. Statistical significance was set at $p < 0.05$.

Results: Out of 126 participants, several factors were significantly associated with severe pneumonia. These included low family income (adjusted odds ratio [AOR] = 3.97, $p = 0.006$), prematurity (AOR = 10.6, $p < 0.001$), male gender (AOR = 3.59, $p = 0.010$), severe stunting (AOR = 1.24, $p = 0.007$), and household overcrowding (AOR = 9.1, $p < 0.001$). Exclusive breastfeeding showed a modest association (AOR = 1.58). Interestingly, older children from relatively higher-income households also demonstrated increased odds of severe pneumonia, suggesting a complex interaction of socioeconomic and environmental determinants. Prior healthcare utilization and nutritional status further contributed to disease severity.

Conclusion And Implications For Translation: The study highlights that severe childhood pneumonia is influenced by a combination of biological, nutritional, and socioeconomic factors. Early identification of high-risk children, improved nutrition, reduction of household overcrowding, and strengthened care-seeking behaviors are essential to reduce disease burden. These findings support the need for targeted public health interventions and context-specific preventive strategies to improve child health outcomes in Pakistan.

Keywords: Childhood pneumonia; Risk factors; Case-control study; Pediatric respiratory infections; Malnutrition; Socioeconomic determinants; Pakistan; Public health interventions

INTRODUCTION

Community-acquired pneumonia (CAP) remains a major public health concern worldwide, particularly among children under five years of age, who are the most vulnerable to severe outcomes and mortality.¹ Globally, pneumonia accounted for approximately 740,180 deaths among children under five in 2019, representing nearly 14% of all deaths in this age group.^{2–4} Despite advances in prevention and treatment strategies, recent estimates suggest that approximately 725,000 children under five continue to die annually due to pneumonia, including around 190,000 neonatal deaths.^{3,4} This translates to the loss of a child every 43 seconds, highlighting the persistent global burden and the urgent need for effective preventive and therapeutic interventions.⁵

The burden of CAP is disproportionately higher in resource-limited settings, where social, environmental, and health system factors converge to increase susceptibility and worsen outcomes. Children living in poverty are particularly at risk due to multiple intersecting determinants, including malnutrition, household air pollution, overcrowded living conditions, and limited access to timely healthcare services.⁶ Established risk factors such as low birth weight, undernutrition, incomplete or absent immunization, non-exclusive breastfeeding, and household overcrowding continue to be highly prevalent in low- and middle-income countries, contributing significantly to disease burden and severity.^{3,5-7} Although global immunization programs, including vaccines against *Streptococcus pneumoniae* and *Haemophilus influenzae* type b (Hib), have led to a reduction in overall incidence, pneumonia remains a leading cause of morbidity and mortality in young children.⁸

In addition, the epidemiology of pneumonia is evolving due to changing socioeconomic conditions, environmental exposures, and variable vaccination coverage across regions. These shifts may alter the distribution and impact of known risk factors; however, up-to-date evidence from many low-resource settings remains limited.⁸ As a result, localized studies are essential to better understand context-specific determinants of disease severity and to guide targeted interventions.

Pakistan bears a substantial burden of under-five morbidity and mortality, with community-acquired pneumonia contributing significantly to both hospital admissions and child deaths. In this context, identifying modifiable and non-modifiable risk factors is critical for designing effective prevention strategies.⁹ However, evidence on the determinants of severe pneumonia in Pakistani children, particularly in the post-pneumococcal vaccine era, remains insufficient and fragmented. This study therefore aims to bridge this gap by analyzing the risk factors associated with severe CAP among children under five in Punjab Province, Pakistan. The findings are expected to inform targeted public health interventions and strengthen child health policies in resource-constrained settings.

Background of the Study

Community-acquired pneumonia is an acute infection of the lungs acquired outside healthcare settings and remains one of the leading infectious causes of death in young children globally. Despite global efforts to reduce its incidence through immunization programs and improved case management, pneumonia continues to impose a heavy disease burden, particularly in low- and middle-income countries. The persistence of high mortality rates suggests that biomedical interventions alone are insufficient without addressing underlying social and environmental determinants.

In developing countries, including Pakistan, multiple risk factors contribute to both the incidence and severity of pneumonia in children. These include malnutrition, poverty, household overcrowding, and indoor air pollution from biomass fuels, inadequate breastfeeding practices, and incomplete immunization coverage. The interaction of these factors creates a high-risk environment for respiratory infections and complicates disease outcomes. Although pneumococcal and Hib vaccines have reduced some disease burden, pneumonia remains prevalent, indicating the presence of additional unresolved risk factors and health system challenges.

Pakistan, in particular, continues to experience high under-five mortality rates, with pneumonia being a leading contributor. However, there is limited context-specific evidence on how socio-demographic, nutritional, and environmental factors interact to influence disease severity in the post-vaccine era. This highlights the need for localized analytical studies to better understand disease patterns and inform effective preventive strategies tailored to the Pakistani population.

Objectives of the Study

The primary objective of this case-control study was to identify and determine the risk factors associated with the severity of community-acquired pneumonia among children under five years of age attending Mayo Hospital, Lahore, Pakistan.

Specific Aims and Hypothesis

Specific Aims

1. To determine the association of socio-demographic factors (gender and family income) with severe community-acquired pneumonia in children under five.
2. To assess the effect of perinatal factors, particularly prematurity and exclusive breastfeeding, on pneumonia severity.
3. To evaluate the role of environmental exposure, specifically household overcrowding and smoking exposure, in the severity of pneumonia.
4. To determine the association between nutritional status (severe stunting) and severity of pneumonia.
5. To assess the effect of immunization status (influenza and pneumococcal vaccination) on severity of community-acquired pneumonia.

Hypothesis

There is a statistically significant association between socio-demographic factors (gender and family income), perinatal factors (prematurity and feeding practices), environmental exposures (household crowding and smoking), nutritional status (severe stunting), and immunization status with the severity of community-acquired pneumonia among children under five years of age in Lahore, Pakistan.

METHODS

Study Design and Setting

A hospital-based case-control study was conducted in the Department of Pediatric Medicine, Mayo Hospital, Lahore, Pakistan, from January to December 2022. Mayo Hospital is a tertiary care teaching hospital that serves a large and socioeconomically diverse population of Punjab Province, making it suitable for assessing pediatric respiratory illnesses and their determinants. The hospital-based design facilitated the recruitment of clinically confirmed cases; however, it may have resulted in a higher proportion of severe cases than would be expected in the general community. The study was reported following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines, an EQUATOR Network reporting standard for case-control studies.

Sample Size Calculation

The sample size was calculated based on detecting a 20% difference in the prevalence of an anticipated risk factor between children with community-acquired pneumonia and controls. Assuming an exposure prevalence of 40% among cases and 20% among controls, with a 95% confidence level, 80% power, and a case-to-control ratio of 1:2, the estimated sample size was approximately 63 cases and 126 controls. However, because the study employed age-matched controls and recruitment was limited to eligible children presenting during the study period, a 1:1 matching approach was adopted. All eligible pneumonia cases identified during the study period were included, and an equal number of age-matched controls were recruited from the same pediatric population. The final sample therefore consisted of 126 participants (63 cases and 63 controls).⁸

Study Participants

A total of 126 children aged 2–59 months were enrolled, including 63 cases diagnosed with community-acquired pneumonia and 63 age-matched controls without pneumonia. Cases were identified using World Health Organization (WHO) clinical criteria. Controls were children attending the pediatric outpatient department or admitted for non-respiratory conditions during the same period. Controls were individually age-matched with cases within an acceptable range of ± 3 months to minimize age-related confounding. Informed consent was

obtained from parents or guardians of all participants. Children with chronic respiratory diseases, immune-compromised conditions, congenital anomalies affecting the respiratory system, or incomplete study data were excluded from the study.

Case Definition

Community-acquired pneumonia was defined according to WHO criteria as the presence of cough or difficulty breathing with age-specific tachypnea:

- ≥ 60 breaths/min (< 2 months)
- ≥ 50 breaths/min (2–11 months)
- ≥ 40 breaths/min (12–59 months)

Severe pneumonia was defined by the presence of danger signs such as central cyanosis, inability to drink or feed, convulsions, lethargy, or severe respiratory distress.

Study Variables

Dependent Variable

- Severity of community-acquired pneumonia (severe pneumonia vs non-severe/control), classified using WHO criteria.

Independent Variables

- Socio-demographic factors: age, gender, family income
- Environmental factors: household crowding, smoking exposure
- Perinatal factors: prematurity, exclusive breastfeeding
- **Nutritional status:** Severe stunting was defined as a height-for-age Z-score (HAZ) below -3 standard deviations (SD) from the median of the WHO Child Growth Standards reference population for children aged 0–59 months.
- **Immunization status: influenza vaccination and pneumococcal vaccination.** Pneumococcal vaccination status was assessed according to Pakistan's Expanded Programme on Immunization (EPI) schedule. Children were categorized as completely vaccinated if they had received the age-appropriate recommended doses of pneumococcal conjugate vaccine (PCV-10) documented on their immunization card, while those with missing or incomplete doses were categorized as incompletely vaccinated.
- **Covariates**
- Maternal education, paternal education, parental occupation, residence (urban/rural), and family structure were recorded for descriptive analysis and potential confounding control.⁸⁻¹⁰

Data Collection

Data were collected using a structured, pre-tested questionnaire and review of medical records. Information included socio-demographic characteristics, feeding practices, vaccination history, environmental exposures, and clinical parameters. Information on exclusive breastfeeding, household smoking exposure, and vaccination history was obtained from parents or caregivers and verified from medical or immunization records whenever available.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as frequencies, percentages, means, and standard deviations where appropriate. Associations between categorical variables and pneumonia severity were assessed using chi-square tests and crude odds ratios (ORs) with 95% confidence intervals (CIs). Variables with $p < 0.05$ in univariate analysis were entered into a multivariable binary logistic regression model to identify independent predictors of severe pneumonia. Adjusted odds ratios (AORs) with 95% CIs were reported. Model fitness was assessed using the Hosmer–Lemeshow goodness-of-fit test. Multicollinearity was evaluated using the variance inflation factor (VIF). A p -value < 0.05 was considered statistically significant.

RESULTS

Socio-demographic characteristics

A total of 126 children were enrolled in the study, with 63 cases and 63 controls. The mean age of participants was 34.11 months (range: 5–59 months), and the mean maternal age was 32.02 years. Overall, 75 (59.52%) children were male and 51 (40.48%) were female, with a male-to-female ratio of 1.47:1. A higher proportion of children resided in rural areas (59.5%) compared to urban areas (40.5%). Regarding socioeconomic status, 57.9% of families reported a monthly income of $\leq 50,000$ rupees. More than half of the children (53.97%) belonged to extended family systems. Parental education levels were low, with 35.7% of fathers and 73.0% of mothers being illiterate. Fathers were most commonly engaged in labor-based occupations (20.6%), while 81.0% of mothers were housewives (Table 1).

Table 1. Frequency distribution of parental characteristics

Variables	Category	Frequency	Percentage
Father's Education	Illiterate	45	35.7
	Literate	81	64.3
Mother's Education	Illiterate	92	73.0
	Literate	34	27.0
Father's Occupation	Laborer	26	20.6
	Businessman	22	17.5
	Skilled worker	8	6.3
	Unskilled worker	24	19.0
	Others	46	36.5
Mother's Occupation	Housewife	102	81.0
	Working women	24	19.0

Note: Data presented as frequency and percentage of total participants (n = 126).

Child and household characteristics

Among all participants, 37.3% of children were born prematurely, 51.6% were exclusively breastfed, and 60.3% were exposed to household smoking. Influenza vaccination was received by 47.6% of children, while 46.0% had

incomplete pneumococcal vaccination status. Household crowding was observed in 59.5% of cases. In the case group, 69.8% of children were male compared to 49.2% in controls. Paternal illiteracy was more frequent among cases (42.9%) than controls (28.6%), while maternal illiteracy was similarly high in both groups (73.0%) (Table 2).

Table 2 Frequency Distribution of the predictors

Variables	Category	Frequency	Percentage
Prematurity	Yes	47	37.3
	No	79	62.7
Exclusive Breast Feeding	No	61	48.4
	Yes	65	51.6
Smoking Exposure	Yes	76	60.3
	No	50	39.7
Previous Hospitalization	Yes	59	46.8
	No	67	53.2
Influenza Vaccine	No	66	52.4
	Yes	60	47.6
Pneumonia Vaccine	incomplete	58	46.0
	Complete	68	54.0
Sever Stunting	No	70	55.6
	Yes	53	42.1

Bivariate analysis of risk factors for severe pneumonia

Significant associations were observed between severe pneumonia and several factors, including low family income, prematurity, lack of exclusive breastfeeding, smoking exposure, incomplete influenza vaccination, household crowding, and severe stunting. Children from lower-income households and those exposed to household crowding were significantly more likely to develop severe pneumonia (Table 3).

Table 3 Demographic and epidemiological risk factors analysis associated with Pneumonia.

Variables and description		Study Groups		Total	p-value	OR
		Case	Control			
Family Income	≤50,000	42	31	73	0.047	2.065 (1.00-4.24)
		66.7%	49.2%	57.9%		
	>50000	21	32	53		

		33.3%	50.8%	42.1%		
Family Type	Extended	31	27	58	0.475	1.29 (0.64-2.61)
		49.2%	42.9%	46.0%		
	Nuclear	32	36	68		
		50.8%	57.1%	54.0%		
Prematurity	Yes	35	12	47	<0.001	5.31 (2.38-11.84)
		55.6%	19.0%	37.3%		
	No	28	51	79		
		44.4%	81.0%	62.7%		
Exclusive breast feeding	No	42	19	61	<0.001	4.63 [2.19-9.81]
		66.7%	30.2%	48.4%		
	Yes	21	44	65		
		33.3%	69.8%	51.6%		
Smoking Exposure	Yes	45	31	76	0.011	2.58 [1.23-5.39]
		71.4%	49.2%	60.3%		
	No	18	32	50		
		28.6%	50.8%	39.7%		
Prev. hospitalization	Yes	32	27	59	0.372	1.13 [0.68-11.8]
		50.8%	42.9%	46.8%		
	No	31	36	67		
		49.2%	57.1%	53.2%		
Influenza Vaccine	No	42	24	66	<0.001	3.25 [1.56-6.74]
		66.7%	38.1%	52.4%		
	Yes	21	39	60		
		33.3%	61.9%	47.6%		
Pneumonia Vaccine status	Incomplete	28	30	58	0.721	0.88 [0.44-1.77]
		44.4%	47.6%	46.0%		
	Complete	35	33	68		
		55.6%	52.4%	54.0%		

House Crowding	Yes	49	26	75	<0.001	4.98 [2.29-10.83]
		77.8%	41.3%	59.5%		
	No	14	37	51		
		22.2%	58.7%	40.5%		
Sever stunting	Yes	33	20	53	0.023	2.31 (1.08-5.24)
		57.1%	31.7%	42.1%		
	No	27	43	70		
		42.8%	68.2%	55.6%		

Multivariable logistic regression analysis

In multivariable logistic regression analysis, the following variables were independently associated with severe pneumonia:

- Male gender (adjusted odds ratio [AOR] = 3.59; $p = 0.010$)
- Low family income ($\leq 50,000$ rupees) (AOR = 3.97; $p = 0.006$)
- Prematurity (AOR = 10.60; $p < 0.001$)
- Household overcrowding (AOR = 9.11; $p < 0.001$)
- Severe stunting (AOR = 1.24; $p = 0.007$)

Prematurity and household overcrowding showed the strongest associations with severe pneumonia.

Model diagnostics

The logistic regression model demonstrated good fit (Hosmer–Lemeshow test: $p = 0.26$), no evidence of multicollinearity (variance inflation factor = 2.81), and acceptable discriminatory ability (area under the receiver operating characteristic curve = 0.7483).

Covariates and additional findings

Several variables showed significant associations in unadjusted analysis but were not independently associated with severe pneumonia after adjustment, including exclusive breastfeeding, smoking exposure, and influenza vaccination status. Pneumococcal vaccination status was not significantly associated with disease severity in either unadjusted or adjusted analyses. Household crowding remained a strong and consistent predictor across both crude (odds ratio = 4.98) and adjusted analyses (AOR = 9.11; $p < 0.001$).

Table 4. Multivariable logistic regression analysis of factors associated with severe pneumonia in under-five children

Predictor	β	p-value	Crude OR (95% CI)	Adjusted p-value	Adjusted OR (95% CI)
Gender (male)	1.28	0.018	2.39 (1.15–4.96)	0.010	3.59 (1.36–9.49)
Family income $\leq 50,000$	1.38	0.047	2.06 (1.00–4.24)	0.006	3.97 (1.48–10.67)

Prematurity	2.36	<0.001	5.31 (2.38–11.84)	<0.001	10.60 (3.63–30.90)
Exclusive breastfeeding	0.46	<0.001	4.63 (2.19–9.81)	0.340	1.58 (0.62–4.23)
Smoking exposure	0.19	0.011	2.58 (1.23–5.39)	0.681	1.22 (0.47–3.15)
Severe stunting	1.15	0.101	1.21 (0.85–1.48)	0.007	1.24 (1.06–1.72)
Influenza vaccine	0.21	<0.001	3.25 (1.56–6.74)	0.657	1.23 (0.49–3.07)
Household crowding	2.21	<0.001	4.98 (2.29–10.83)	<0.001	9.11 (3.25–25.58)

Figure 1 illustrates the multivariable logistic regression results showing adjusted odds ratios (AORs) and 95% confidence intervals for factors associated with severe community-acquired pneumonia in children under five years. Prematurity and household overcrowding demonstrated the strongest positive associations with disease severity, followed by family income, gender, and severe stunting (Figure 1).

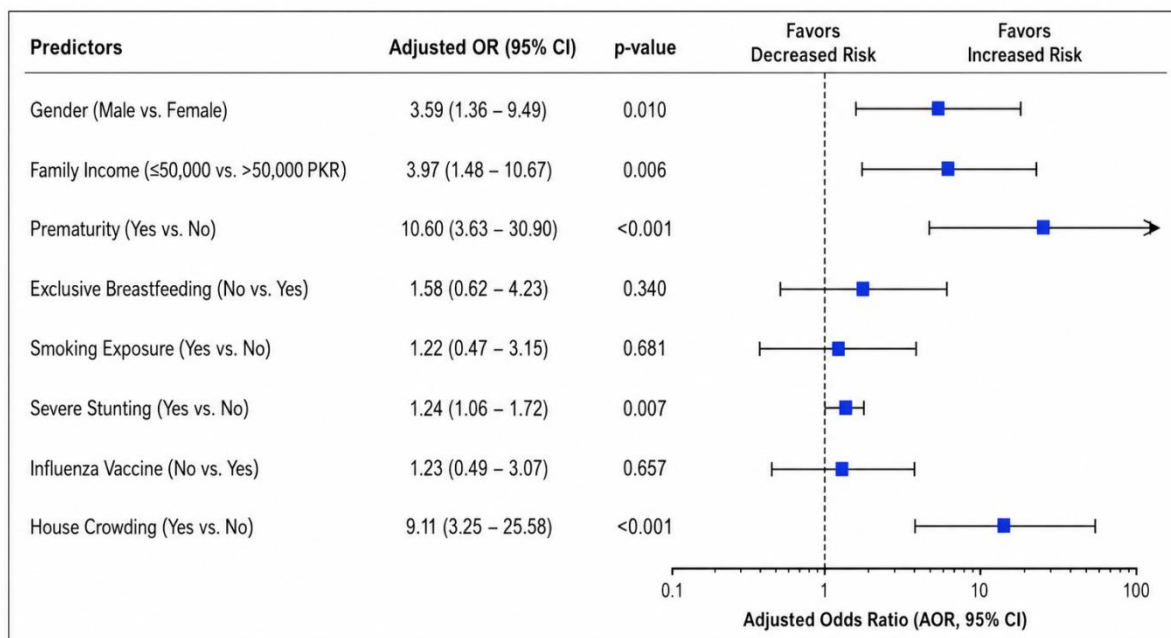


Figure 1. Multivariable logistic regression analysis showing adjusted odds ratios (AOR) and 95% confidence intervals for factors associated with severe community-acquired pneumonia in children under five years.

Note: OR = Odds Ratio; CI = Confidence Interval; PKR = Pakistani Rupees.

Figure 1. Forest plot of adjusted odds ratios for severe pneumonia risk factors

DISCUSSION

The present study investigated the risk factors associated with community-acquired pneumonia among children under five years of age in Punjab Province, Pakistan. Using a hospital-based case-control design, this study identified male gender, low family income, prematurity, and household crowding as independent predictors of pneumonia. The use of standardized WHO criteria for pneumonia diagnosis and systematic data collection strengthens the validity of these findings. Despite improvements in childhood vaccination coverage, pneumonia remains a major cause of morbidity among young children, particularly in low- and middle-income countries where biological vulnerability and socioeconomic inequalities continue to influence disease risk.^{11,12}

Male children had significantly higher odds of community-acquired pneumonia compared with female children after adjustment for potential confounding factors (AOR 3.59, 95% CI 1.36–9.49). This finding is consistent with previous studies reporting increased susceptibility to respiratory infections among male children.^{13,14} Biological differences, including variations in immune maturation, airway structure, lung development, and

hormonal regulation of immune responses, may contribute to increased vulnerability among boys. Recent evidence suggests that male infants may have less mature immune responses and reduced respiratory adaptation compared with females, which may increase the risk of lower respiratory tract infections.^{13,15} These findings emphasize the importance of timely recognition and management of respiratory symptoms in all children, while considering potential sex-related differences in disease susceptibility.

Socioeconomic disadvantage was identified as an important independent determinant of pneumonia in this study. Children from families with monthly income $\leq 50,000$ PKR had nearly four times higher odds of pneumonia compared with children from higher-income households (AOR 3.97, 95% CI 1.48–10.67). Similar associations between poverty and childhood pneumonia have been documented in Pakistan and other resource-limited settings.^{16,17} Low socioeconomic status may increase pneumonia risk through multiple pathways, including inadequate nutrition, poor housing conditions, delayed healthcare-seeking, and limited access to preventive and curative health services. Recent evidence highlights that socioeconomic inequalities remain among the most important contributors to childhood pneumonia burden globally.¹⁸ Strengthening primary healthcare services, improving caregiver awareness, and reducing financial barriers to healthcare access are therefore essential components of pneumonia prevention strategies.

Prematurity emerged as the strongest independent predictor of community-acquired pneumonia in the present study. Premature children had more than ten-fold higher odds of pneumonia compared with children born at term (AOR 10.60, 95% CI 3.63–30.90). This association is biologically plausible because premature infants have immature lungs, reduced pulmonary reserve, impaired mucociliary clearance, and underdeveloped immune responses, increasing their susceptibility to respiratory infections.¹⁹ Recent studies have consistently demonstrated that preterm birth is associated with increased risk of childhood pneumonia and severe respiratory outcomes, particularly in low-resource settings.²⁰ These findings highlight the need for enhanced preventive care, close follow-up, and early identification of respiratory illness among premature infants.

Household crowding was another major independent predictor of pneumonia in this study (AOR 9.11, 95% CI 3.25–25.58). Crowded living environments increase close contact between household members, facilitate respiratory pathogen transmission, and may be associated with poor ventilation and increased exposure to infectious agents. Previous studies from South Asia and other low- and middle-income countries have identified household overcrowding as an important risk factor for childhood pneumonia.^{21,22} Interventions aimed at improving housing conditions, reducing overcrowding, and promoting respiratory hygiene practices may contribute to reducing childhood pneumonia transmission.

Nutritional status remains an important factor in childhood respiratory health. Although severe stunting was associated with pneumonia in preliminary analyses, its independent effect should be interpreted cautiously until the regression estimates are confirmed. Malnutrition is a recognized contributor to childhood pneumonia through impaired immune function, reduced respiratory muscle strength, and altered lung development.²³ Recent evidence continues to demonstrate that under-nutrition increases susceptibility to respiratory infections and worsens clinical outcomes among young children.²⁴ Therefore, nutritional screening and integration of nutrition interventions into child health programs remain essential components of pneumonia prevention.

In the present study, exclusive breastfeeding, smoking exposure, and influenza vaccination were not significantly associated with pneumonia after adjustment. These findings should be interpreted cautiously, as the relatively small sample size may have limited the ability to detect moderate associations. Additionally, relatively high vaccination coverage and limited variation in exposure patterns within the study population may have reduced the observed effect of individual preventive factors. Previous studies have demonstrated that the protective effects of breastfeeding and immunization may vary according to population characteristics, pathogen distribution, and the presence of other stronger socioeconomic and environmental determinants.^{22,23}

The persistence of childhood pneumonia in the post-pneumococcal vaccine era indicates that vaccination alone cannot eliminate the disease burden. Although pneumococcal vaccination has substantially reduced vaccine-preventable pneumonia, other bacterial and viral pathogens, along with persistent risk factors such as prematurity, poverty, overcrowding, and malnutrition, continues to contribute to childhood pneumonia occurrence. Integrated approaches combining immunization programs with improvements in maternal health,

nutrition, housing conditions, and timely access to healthcare are essential for further reducing pneumonia-related morbidity and mortality.

Strengths and Limitations

This study has several strengths. The case–control design allowed for the identification of multiple risk factors associated with disease severity. The use of standardized WHO diagnostic criteria ensured consistency in case identification, while structured and comprehensive data collection enhanced data quality. Furthermore, focusing on Punjab Province increases the relevance of findings for regional public health planning and targeted interventions.

However, certain limitations should be acknowledged. The reliance on caregiver recall for some exposure variables introduces the possibility of recall bias. Additionally, as the study was facility-based, findings may not be fully generalizable to all community settings. Residual confounding due to unmeasured variables may also be present.

Future research should consider prospective community-based designs and explore biological and environmental interactions in greater depth to better understand pneumonia risk patterns in early childhood.

CONCLUSION

This study identified male gender, low socioeconomic status, prematurity, and household crowding as important independent predictors of community-acquired pneumonia among children under five years in Punjab, Pakistan. Prematurity and overcrowded living conditions were the strongest associated factors, highlighting the need for targeted preventive strategies for vulnerable children. Strengthening maternal and neonatal care, improving household conditions, promoting early healthcare-seeking behavior, and ensuring equitable access to primary healthcare services may help reduce the burden of childhood pneumonia.

Conflicts of interest

The authors declare no competing interests.

Financial disclosure

Nothing to declare.

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There was no funding for this study.

Ethics approval

Ethical approval for this study was obtained from the Institutional Review Board (IRB) of the University of Punjab prior to data collection. Written informed consent was obtained from all participants' caregivers before enrolment in the study.

Declaration of patient consent

Written informed consent was obtained from the parents or legal guardians of all participating children prior to data collection. The study ensured confidentiality and anonymity of all participants, and data were used solely for research purposes.

Use of artificial intelligence (AI) – assisted technology for manuscript preparation

The authors confirm that Artificial Intelligence (AI)–assisted technology (ChatGPT) was used only for language editing, grammar improvement, and formatting support during manuscript preparation. No AI tools were used

for data analysis, interpretation, or generation of scientific findings. All content was critically reviewed, verified, and approved by the authors, who take full responsibility for the final manuscript.

Disclaimer

None.

Key messages

- Severe pneumonia in under-five children was significantly associated with male gender, severe stunting, and delayed care-seeking.
- Malnutrition remain critical modifiable risk factors in reducing pneumonia severity in low-resource settings.
- Strengthening early detection, nutrition interventions, and primary healthcare access can substantially reduce pneumonia-related morbidity and mortality.

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