Research Article

Trends in Admissions and Mortality of Pediatric Community-Acquired Pneumonia in a Tertiary Care Hospital: A Cross-Sectional Study

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Abstract

Background: Pediatric pneumonia poses a substantial global health threat and with the significant global and changes in climate, mapping recent trends in infectious disease dynamics such as pneumonia becomes imperative.
Objectives: This study aimed to evaluate seasonal trends in pediatric community-acquired pneumonia admissions and mortality and their correlation with meteorological factors.
Methods: This cross-sectional study was conducted from March 2023 to February 2024 at Mayo Hospital Lahore, involving children aged 15 years and younger diagnosed with community acquired pneumonia. Data on admissions, demographics, comorbidities, pneumonia type, and meteorological variables were extracted from hospital records and the Pakistan Meteorological Department.
Results: Among 690 pediatric patients, 91.1% were under 5 years, 56% were male, and 34% had bronchopneumonia. The odds of mortality were significantly raised in patients with bronchopneumonia (OR=3.379; 95%-CI: 2.171-5.260) and co-morbidities such as sepsis (OR=5.658; 95%-CI: 2.627-12.185). There was a significant distribution of pneumonia cases across different seasons (P<0.001) with the highest occurring in winter (36.4%) Mortality was highest in February 2024 (21%) and May 2023 (19.5%). While meteorological factors showed no significant correlation with the number of admissions due to pneumonia, higher and precipitation (r=-0.677; P=0.016) were significantly correlated with decreased mortality. Furthermore, pneumonia cases differed significantly across months based on age (P<0.001), gender (P=0.031), and type of pneumonia (P<0.001).
Conclusion: Number of admissions and mortality pediatric CAP exhibit significant seasonal variations. Mortality is significantly influenced by mean monthly temperature, total monthly precipitation, pneumonia type, and comorbidities, particularly sepsis.
Keywords: Pneumonia, Community-Acquired, Pediatric, Seasonal Variation, Mortality, Comorbidity, Temperature
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Introduction

Pediatric pneumonia is a major global health issue, causing about 14% of deaths in children under five, particularly in South Asia and Sub-Saharan Africa.[1] Although it occurs year-round, incidence peaks in winter and early spring, suggesting a link between seasonal environmental factors and pneumonia rates.[2]

For instance, a 1°C change in temperature has been shown to increase the relative risk of pneumonia episodes by 1.06 times and pediatric hospital admissions by 1.10 times.[3] Studies from tropical regions have further demonstrated significant associations between viral pneumonia and meteorological variables such as relative humidity and precipitation.[4] In Pakistan, a study conducted in the Bannu district highlighted a higher prevalence of lower respiratory tract infections (LRTIs), including pneumonia, during the winter months (e.g., February), with a decreasing trend until mid-year and a subsequent rise from October to December.[5] Similarly, the study by Erling et al. in 1999 conducted in Lahore demonstrated that the prevalence of LRTIs was significantly negatively correlated with the monthly average minimum daytime temperature.[6]

Pneumonia seasonality reflects pathogen responses to climate. Temperature changes are linked to Mycoplasma pneumoniae, respiratory syncytial virus (RSV), and

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pneumococcus.[4,7] Humidity and rainfall influence parainfluenza, adenovirus, and Chlamydia trachomatis.[4] RSV peaks in November–December, whereas Mycoplasma pneumoniae, including resistant strains, increases from May to July.[7,8]

Despite the high burden of community-acquired pneumonia, evidence on the impact of temperature and precipitation in arid climates like Lahore is scarce, with only one outdated local study. Given pediatric vulnerability, this study examined monthly and seasonal pneumonia patterns and their correlation with meteorological factors and related mortality. [6,9]

Methods

This was an analytical cross-sectional study conducted between March 2023 and February 2024 at Mayo Hospital, Lahore, Pakistan. The inclusion criteria included children aged 15 years or younger admitted to the pediatric ward. Pediatric community-acquired pneumonia (CAP) was defined as acute pulmonary infiltration observed on a postro-anterior (PA) chest X-ray, along with at least two of the following symptoms: fever, cough, and purulent sputum. CAP cases were limited to children ≤15 years who had no recent hospitalizations or significant healthcare exposure. Exclusion criteria included patients with underlying respiratory conditions or chronic lung diseases (e.g., cystic fibrosis, bronchiectasis, patients with congenital lung anomalies or structural abnormalities, and patients with duplicate records or readmissions.

A non-probability consecutive sampling technique was used where all available cases of pneumonia within the specified study period were included. Sample size calculation was not applicable as the study was planned to rely on pre-existing data from hospital records. Data were extracted directly from the hospital registers and medical records of both the pediatric wards and ICU in the Department of Pediatrics, Mayo Hospital Lahore. Information regarding the date of admission, age, sex, comorbidities, and type of pneumonia was retrieved. Pneumonia patients were classified based on chest X-ray appearance. On chest X-ray, pneumonia was categorized as either bronchopneumonia or lobar pneumonia. Bronchopneumonia shows patchy, perihilar infiltrates with scattered reticulonodular opacities, while lobar pneumonia presents as a well-defined, homogeneous consolidation of one or more lobes with visible air bronchograms. Data regarding meteorological variables, including mean monthly temperature, mean monthly relative humidity, and total monthly precipitation, were extracted from the Pakistan Meteorological Department website (https://cdpc.pmd.gov.pk/).

The association between demographic variables and monthly distribution of pneumonia cases and deaths was assessed using the chi-square test of independence. For the seasonal distribution of pneumonia cases, the chi-square test of goodness-of-fit was utilized. Bivariate correlation analysis was conducted to explore relationships between pairs of variables, examining associations between environmental variables and total number of pneumonia cases and deaths in each month. Pearson or Spearman correlation coefficients were computed to assess the strength and direction of these relationships. All data analyses were performed using SPSS version 27.

Results

The general characteristics of study population are provided in Table 1. A total of 690 pediatric patients presented with pneumonia during the study period, with a mean age of approximately 24 months. Among these patients, majority were under the age of 5 years and were suffering from lobar pneumonia. The most common comorbidities identified were measles and sepsis.

Out of 690 patients with pneumonia, 96 (14%) died, while 512 (74.2%) completely recovered and were discharged. The study evaluated two predictors of mortality in pneumonia patients: presence of comorbidities and the type of pneumonia.

The presence of comorbidities was significantly associated with increased mortality (X^2=31.040; P <0.001). Patients with comorbidities had 3.47 times higher odds of mortality compared to those without comorbidities (OR=3.47; 95% CI: 2.200-5.477). Specifically, the presence of sepsis was a significant predictor of mortality (X^2=24.155; P <0.001), with patients having sepsis showing 5.658 times higher odds of death compared to those without sepsis (OR=5.658; 95% CI 2.627-12.185). Although measles was the most common comorbidity in our population, it was not significantly associated with mortality (X^2=1.706; P=0.191). Other less common comorbidities were also significant predictors of mortality (X^2=9.462; P =0.002); however, individual evaluation was not possible due to the small number of patients.

Regarding the type of pneumonia, 56 (58.3%) deaths occurred in patients with bronchopneumonia, while 40 (41.6%) deaths were reported in those with lobar pneumonia. The presence of bronchopneumonia was significantly associated with increased mortality (X^2=31.363; P <0.001), with patients having 3.379 times higher odds of death compared to those with lobar pneumonia (OR=3.379; 95% CI: 2.171-5.260).

There was a significant seasonal variation in number of admissions due to pneumonia (X^2=135.426; P <0.001), with higher rates observed in spring (34.7%) and winter (36.4%), compared to summer (19%) and autumn (9.8%). Regarding monthly distribution, the highest number of cases occurred in January 2024 (16%), corresponding to the winter season, while the lowest number was reported in August 2023 (0.6%). There was a gradual decline in cases from March 2023 to July 2023 (14% to 8%). August

to October 2023 saw lower case numbers (0.6% to 2.5%), followed by an increase from November 2023 to January 2024 (5.3% to 16%)

In terms of deaths, out of the total 96 deaths, February 2024 specifically had the highest number of deaths (21%). However, the months with the highest mortality were May 2023 (19.5%), December 2023 (22%), and February 2024 (22.2%). The monthly trends in deaths were similar tothose of the total number of pneumonia cases,with no

Table 1: *Characteristics of study population. (LAMA= Left against medical advice; DOR=Discharged on request)*

Parameter	Variable	Frequency
Age	<5 years	629
	5-14 years	51
Gender	Male	387
	Female	300
Diagnosis	Bronchopneumonia	230
	Lobar pneumonia	460
Co-morbidities	Measles	68
	Sepsis	29
	Meningitis	10
	Cerebral palsy	10
	Fits	5
	Diarrhea	5
	Severe acute malnutrition	3
	Septic shock	3
	Down syndrome	2
	Myocarditis	2
	Asthma	1
	Bronchiolitis	1
	Croup	1
	Tuberculosis	1
	Eye and skin infections	3

Disease outcome	Died	96
	LAMA	75
	DOR	5
	Absconded	2
	Discharged	512

deaths occurring from July 2023 to October 2023.

The mean monthly temperature and total monthly precipitation showed a negative correlation with the number of admissions due to pneumonia, suggesting that an increase in temperature, RH, and precipitation might potentially decrease the number of pneumonia cases. However, these correlations were not statistically significant (see Table 2). A threshold of 20°C for temperature and 70% for RH was identified, and a linear regression model was used. This analysis also yielded statistically non-significant results for both temperature and relative humidity (Temperature: beta=-0.021, P value=0.970; RH: beta=0.355, P value =0.424). In contrast, statistically significant correlations were found between deaths due to pneumonia and temperature, as well as precipitation but not with RH, indicating fewer deaths with increasing temperature or precipitation (see Table 2)

Table 2: *Correlation of temperature and precipitation with pneumonia cases and deaths in each month*

Meteorological variable	Correlation with total pneumonia cases [r (P value)]	Correlation with no. of deaths due to pneumonia [r (P value)]
Temperature	-0.483 (0.111)	-0.624 (0.03)
Relative humidity	-0.211 (0.511)	-0.222 (0.488)
Precipitation	-0.382 (0.221)	-0.677 (0.016)

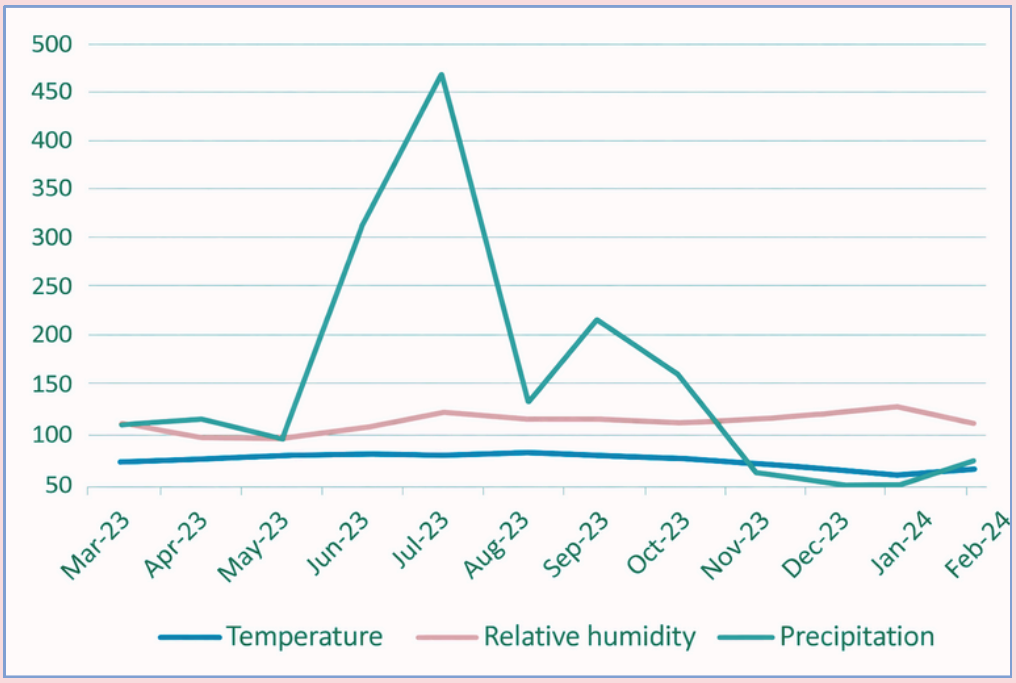

Figure 1: *Variations of meteorological variables during the study duration*

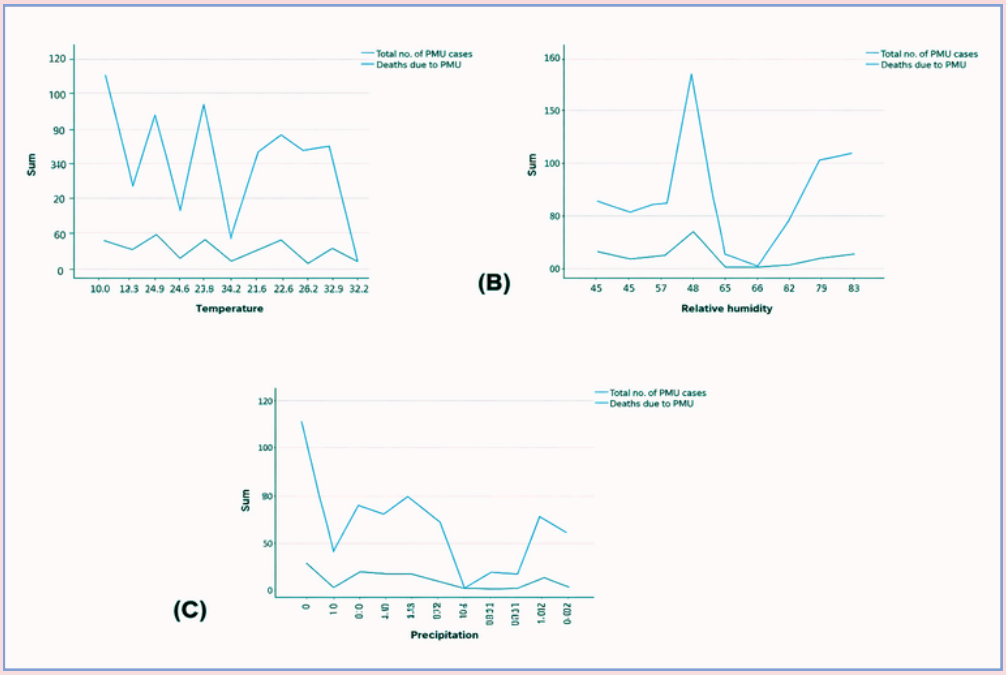

Figure 2: *(A) Variation in pneumonia (PNEU) cases and deaths due to temperature. (B): Variation in pneumonia cases and deaths due to Relative humidity. (C): Variation in pneumonia cases and deaths due to precipitation.*

The observed pattern of pneumonia admissions across months significantly differed by age (X^2=103.361; P<0.001), gender (X^2=21.218; P=0.031), and type of pneumonia (X^2=41.215; P<0.001). The detailed trends are presented in Table 3.

Regarding gender, pneumonia admissions were significantly higher in the male population compared to the female population in March 2023 (67.7% vs. 32.3%), . May 2023 (67.5% vs 32.4%), June 2023 (55.5% vs. 44.4%), January 2024 (61.2% vs. 38.7%), and February 2024 (56.6% vs. 43.3%). The remaining months showed a female predominance, with the highest rate in July 2023 (58.2%). August 2023 had an equal number of male and female cases, while April 2023 had comparable numbers in both genders. The monthly distribution of male pneumonia cases varied more significantly than female cases.

Table 3: *Pattern of Pneumonia admissions based on Age, Gender and Type.*

Months	Age [n (%)]		Gender [n (%)]		Type of pneumonia [n (%)]	
	<5 years	5-14 years	Male	Female	Broncho-pneumonia	Lobar pneumonia
Mar 2023	94 (97.9)	2 (2.1)	65 (67.7)	31 (32.3)	31 (32.3)	65 (67.7)
Apr 2023	64 (95.5)	3 (4.5)	33 (49.2)	34 (50.8)	28 (41.8)	39 (58.2)
May 2023	72 (93.5)	5 (6.5)	52 (67.5)	25 (32.8)	27 (35)	50 (65)
Jun 2023	70 (97.2)	2 (2.8)	40 (55.5)	32 (44.5)	34 (47.2)	38 (52.8)
Jul 2023	44 (80)	11 (20)	23 (41.8)	32 (58.2)	24 (43.6)	31 (56.4)

Aug 2023	1 (25)	3 (75)	2 (50)	2 (50)	0 (0)	4 (100)
Sep 2023	6 (42.8)	8 (57.2)	6 (42.8)	8 (57.2)	1 (7.1)	13 (92.9)
Oct 2023	14 (82.3)	3 (17.7)	8 (47)	9 (53)	5 (29.4)	12 (70.6)
Nov 2023	33 (89.1)	4 (10.9)	17 (45.9)	20 (54.1)	2 (5.4)	35 (94.6)
Dec 2023	49 (98)	1 (2)	22 (46.8)	25 (53.2)	8 (16)	42 (84)
Jan 2024	97 (96)	4 (4)	68 (61.2)	43 (38.8)	45 (40.5)	66 (59.5)
Feb 2024	85 (94.4)	5 (5.6)	51 (56.6)	39 (43.4)	25 (27.7)	65 (72.3)

Discussion

Previous studies suggest that climatic factors more significantly affect the transmissibility and infection rates of viral pathogens compared to bacterial pathogens.[4,10] It is also well-established that viral infections can predispose individuals to secondary bacterial infections.[11] As viral pathogens, particularly influenza and RSV, peak in the winter and spring, bacterial pneumonia prevalence also rises during these seasons.[4] This leads to higher in-hospital admissions and increased mortality rates from pneumonia, as supported by our findings.[4,12]

Since viral pneumonia is subject to seasonal variations, meteorological factors such as temperature, relative humidity, precipitation, air flow and ventilation have been studied as potential causes of this seasonality.[13] It has been proposed that increased temperature and humidity affect the transmissibility of these pathogens by increasing the droplet size of aerosols, resulting in decreased airborne time and thus decreasing transmissibility.[14] These factors also affect infectivity by impacting the stability of viruses; for instance, high relative humidity decreases the stability of influenza and respiratory syncytial viruses, leading to decreased virulence.[13]

However, in our study, although the trend showed an increase in pneumonia cases as temperature and relative humidity increased, no statistically significant correlation was found between them which contradicts some previous studies.[6] Several important reasons should be considered regarding this. First, due to limitations in data availability, our study considered data for only 12 months. Longer studies spanning >3 years might demonstrate a significant correlation.[15] Second, due to the unavailability of data, viral and bacterial pneumonia could not be separately analyzed. Third, geographical variations in effect of climate on disease burden may play a role, as previous studies assessing the relationship between temperature, relative humidity, and COVID-19 incidence indicated non-significant associations in Pakistan but significant associations in other geographical locations.[16,17] Thus, temperature may be a significant contributor to the seasonality of pneumonia incidence in Europe and subtropical regions like China but less significant in regions like South Asia.[18]

There was some collinearity between temperature and humidity (variance proportion = 0.98), so we also examined the combined effect of temperature and relative humidity using an interaction term. Although this analysis yielded non-significant results, the p-value was 0.058, which is close to the threshold for significance ($p < 0.05$). Specifically, temperature appears to play a permissive role in the effect of relative humidity on respiratory viruses.[13] Research shows that at 20°C, transmission efficiency peaks at 20-35% RH but is absent at 80% RH. Conversely, at 5°C, transmission efficiency consistently decreases as relative humidity increases.[19]

Regarding precipitation, past studies have shown highly heterogeneous results in its association with pneumonia and other respiratory diseases.[13] Studies that found a correlation between respiratory infections like legionnaires' disease and precipitation were mostly conducted in warm temperate and tropical regions.[20] In contrast, regions with arid and semi-arid climates, such as that occur in Pakistan, show a less profound and more sporadic association.[6,10] The low number of cases reported during the monsoon season of July and August 2023 (8.5%) contradicts some reports that demonstrate a higher incidence of respiratory infections during this season in Pakistan.[21]

Temperature extremes have been linked to increased mortality regardless of the condition.[22] Our study observed a negative correlation between environmental temperature and pneumonia-related mortality, indicating that lower temperatures tend to increase mortality. This finding aligns with previous studies showing that cold

temperatures pose a greater risk of morbidity and mortality due to pneumonia, especially cases caused by influenza and RSV.[4,6,10] Several important factors could explain this correlation. First, as previously mentioned, the winter season sees a higher prevalence of viral pneumonia cases with superimposed bacterial infections, potentially increasing mortality under low temperatures.[11] Second, cold temperatures reduce the innate immune response against respiratory viruses, resulting in more severe infections.[23] Third, our study population consisted of pediatric patients who are more vulnerable to temperature changes due to their developing immune systems, thus showing significant mortality related to temperature changes.[9]

The correlation of mortality with precipitation was also found to be significant, although its practical importance is less clear. It is possible that during dry, arid months, air pollution especially in the form of photochemical smog is at its peak, particularly in Lahore where the study was conducted. These pollutants can irritate the respiratory passages, weaken mucous responses, and entrap pathogens, leading to more severe diseases and increased mortality.[24]

Apart from the seasonal predictors, our study also focused on two other predictors of mortality: the type of pneumonia and the presence of comorbidities. Bronchopneumonia was associated with significantly higher odds of mortality than lobar pneumonia (OR=3.379; 95% CI: 2.171-5.260). Although the clinical significance of this might be questionable, it could be due to the more insidious course of bronchopneumonia, resulting in later diagnosis and increased severity compared to lobar pneumonia, which usually has a more acute onset.[25] In this study, all types of pneumonia that followed a lobar pattern of distribution in the alveoli were classified as lobar pneumonia.

A more clinically significant predictor was the presence of comorbidities, which increased the odds of death among pneumonia patients (OR=3.47; 95% CI: 2.200-5.477). The most common comorbidity was measles, a significant childhood infection in Pakistan. Although measles-associated pneumonia is a relatively uncommon presentation, it still occurs in significant numbers during outbreaks, which mostly occur around the spring season from March to June. In our population, 86.7% of measles cases were present in these months. Despite this increased occurrence, measles was not associated with increased mortality. The second most common comorbidity was sepsis. Although sepsis can be considered a sequela of pneumonia, as severe infection can lead to systemic inflammation, it was considered a separate entity in this study to capture the overall burden of pneumonia in our population. The presence of sepsis significantly raised the odds of mortality in our study population (OR=5.658; 95% CI: 2.627-12.185). Thus, the most clinically significant predictor of mortality identified in our study was the presence of sepsis. This study is limited by small sample size, short duration, and lack of etiological data, as well as its retrospective design, which precluded analysis of socio-behavioral factors. Nonetheless, the findings aid in predicting seasonal pneumonia trends and identifying mortality predictors. Stratification by age, gender, and pneumonia type may help identify high-risk groups and improve surveillance.

Conclusion

Pediatric community-acquired pneumonia shows significant seasonal variation in admissions and mortality, despite no link with overall meteorological factors. Mortality was predicted by temperature, precipitation, pneumonia type, and comorbidities, especially sepsis. Recognizing these trends can improve surveillance and guide targeted prevention and intervention strategies.

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Authors' Contributions:
MZR, SB, NU: Conceptualization, Methodology, Writing Original Draft.
SA, MUH: Investigation, Data Curation, Formal Analysis and contributed in writing original draft.
SS, MZ: Design of study, revise critically and final Review & Editing.

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