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Original Research Article

Seasonal Variations in Acute Asthma Exacerbation: A Hospital-Based Observational Study

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Abstract

Background: Asthma is a major global cause of chronic respiratory morbidity, with acute exacerbations driving emergency visits, hospitalisations and health-care costs. Seasonal patterns in exacerbations have been demonstrated in many populations, driven by complex interactions between respiratory viruses, aeroallergens, air pollution and meteorological conditions. However, data from subtropical regions, particularly in South Asia, remain limited and heterogeneous.

Methods: We have retrospectively observed all the emergency department (ED) visits with acute asthma exacerbation in a teaching hospital with tertiary care in southern India between January 2021 and December 2023. Patients who had asthma diagnosed by physicians, meeting the following eligibility criteria (age ≥5 years; acute deterioration of symptoms; consecutive patients; etc.) were enrolled in the study; patients with COPD, cardiac failure, or other chronic lung disease were excluded. Season (pre-monsoon, monsoon, post-monsoon, winter) and severity of the episodes were categorized based on Global Initiative for Asthma. Multivariate analysis Multivariate logistic regression was used because it was necessary to determine the independent predictors of severe exacerbation (severe or life-threatening vs mild-moderate).

Results: One thousand, five hundred and twenty-four ED visits due to acute asthma exacerbation in 768 distinct patients were analysed. The mean age was 32.42217.1 years; 41.2 percent of the participants were between 5 and 17 years of age, and 55.8 percent were females. All in all, winter had 33.3 percent exacerbations and post-monsoon had 27.1 percent and monsoon and pre-monsoon seasons had 21.4 percent and 18.2 percent respectively ($p < 0.001$). There were a bimodal maximum in the number of months in October and December. The proportion of severe or life-threatening episodes was 18.0% of the visits, more common in winter (22.1) than in other seasons ($p = 0.004$). In multivariate analysis, poor inhaled-controller adherence (aOR 2.11, 95% CI 1.612.77), winter season (aOR 1.68, 95% CI 1.242.27), post-monsoon season (aOR 1.43, 95% CI 1.052.27) and age <18 years (aOR 1.57, 95% CI 1.182.0

Conclusion: In this subtropical setting, acute asthma exacerbations displayed a marked autumn–winter predominance, with winter and post-monsoon periods associated with both higher frequency and greater severity of attacks. These findings support seasonally targeted preventive strategies, including anticipatory treatment optimisation and trigger avoidance during high-risk months.

Keywords: Asthma; Acute Exacerbation; Seasonality; Emergency Department; Hospitalisation; India.

Introduction

Asthma affects an estimated 300 million people worldwide and remains a leading cause of chronic respiratory morbidity, emergency health-care utilisation and impaired quality of life, despite advances in pharmacotherapy and guideline-based care.[1] Global projections suggest that the burden of asthma will continue to rise in coming decades, driven by urbanisation, environmental change and ageing populations.[1] In India, asthma and other chronic respiratory diseases contribute substantially to overall mortality and disability, with a high proportion of outpatient encounters in primary and secondary care attributed to respiratory symptoms.[2] Acute asthma exacerbations defined as episodes of progressively worsening breathlessness, wheeze, cough and chest tightness requiring a change in treatment are responsible for the greatest share of asthma-related costs and are key determinants of disease prognosis.[3,4] Large administrative and epidemiological datasets from high-income countries show that hospitalisations and deaths due to asthma follow distinct seasonal patterns, with pronounced peaks in specific months.[3–6] Weiss and colleagues first highlighted seasonal trends in US asthma hospitalisations and mortality, noting increases in winter and early autumn, particularly among children.[3] Subsequent work from the UK and North America demonstrated that peaks in general practitioner consultations, ED visits and deaths often coincide but can vary with age group and geography.[4,5,15]

The drivers of these seasonal patterns are multifactorial. Viral respiratory infections, especially rhinovirus, respiratory syncytial virus and influenza, are strongly implicated in autumn and winter exacerbation peaks, particularly among school-aged children.[5–7,14]

Aeroallergen exposure (pollens and moulds), meteorological factors (temperature, humidity, barometric pressure) and ambient air pollutants (especially particulate matter and ozone) also modulate exacerbation risk.[6–9,12,13] Recognition of "high-risk seasons" has led to proposals for anticipatory strategies, such as pre-emptive escalation of controller therapy and heightened trigger avoidance during specific months.[6–8,22]

However, most detailed analyses of seasonal trends in asthma exacerbation have originated from temperate, high-income settings.[4–7] Climatic, environmental and behavioural determinants in subtropical and tropical regions—characterised by monsoon cycles, high baseline humidity and different aeroallergen profiles—may produce distinct seasonal signatures. Data from South Asia are relatively sparse and often limited to short study periods, single age groups or ecological correlations with pollution indices.[2,12,20]

Improving understanding of local seasonal patterns is crucial for designing context-specific preventive and therapeutic interventions, especially in rapidly urbanising Indian cities where air pollution, overcrowding and changing lifestyles converge.[2,12,16,20]

The present study aimed to characterise the seasonal variation in acute asthma exacerbations presenting to the ED of a tertiary-care teaching hospital in southern India over a three-year period.

Specifically, we sought to (i) describe the distribution of exacerbations across months and defined climatic seasons; (ii) compare clinical severity and outcomes by season; and (iii) identify seasonal and patient-level predictors of severe exacerbation. We hypothesised that exacerbations would cluster in the post-monsoon and winter months, and that younger age and inadequate controller therapy would amplify the seasonal risk.

Materials and Methods

Study design and setting: The paper was carried out in the form of a retrospective hospital-based observational study in an emergency department in the tertiary-care teaching hospital. The hospital acted as a large referral centre to both adult and paediatric acute respiratory emergency.

Study period: The study period extended from 1 January 2021 to 31 December 2023, encompassing three full calendar years and 36 consecutive months.

Study population: All consecutive ED visits during the study period coded as "acute asthma exacerbation" were screened. Patients were eligible if they had:

- Physician-diagnosed asthma documented in the medical record;
- Age ≥ 5 years; and
- Presentation with acute or subacute worsening of asthma symptoms (breathlessness, wheeze, cough and/or chest tightness) requiring systemic bronchodilator therapy, systemic corticosteroids or other urgent intervention.

We excluded visits where:

- COPD, bronchiectasis, interstitial lung disease or cardiac failure were the primary diagnoses;
- Asthma diagnosis was uncertain or disproportionate to structural lung disease; or
- Key clinical data (month of presentation, severity classification) were missing.

For patients with multiple ED visits during the study period, each visit was treated as a separate exacerbation episode.

Definition of seasons

Using a regional meteorological data, months were grouped according to four seasons:

- **Pre-monsoon (summer):** March–May
- **Monsoon:** June–September
- **Autumn:** October -November.
- **Winter:** December–February
- Climatic seasons were assumed to not change much during the three years.

Data Collection & Variable

Data were taken from electronic medical records using a structured proforma. The following variables were collected:

- Demographics: age, sex.

- Asthma history: duration of asthma, baseline severity, inhaled controller use and self-reported adherence, prior hospitalisations or ICU admissions for asthma.
- Comorbidities: allergic rhinitis, atopic dermatitis, obesity, smoking status (for adults).
- Clinical presentation: vital signs, peak expiratory flow (where available), presence of respiratory infection symptoms (fever, sore throat, rhinorrhoea).
- Exacerbation severity: categorised as mild, moderate, severe or life-threatening based on Global Initiative for Asthma criteria (including clinical signs, PEF and oxygen saturation).
- Treatment and outcomes: ED management (bronchodilators, systemic corticosteroids, adjunct therapies), disposition from ED (discharge, ward admission, ICU admission) and in-hospital mortality.

Outcomes

The primary outcome was the seasonal distribution of ED visits for acute asthma exacerbation. Secondary outcomes included seasonal variation in:

- Proportion of severe or life-threatening exacerbations; and
- Hospitalisation (ward or ICU) following ED presentation.

For regression analyses, severe and life-threatening episodes were combined as "severe exacerbation."

Statistical analysis: Data were analysed in standard statistical software. Mean Standard deviation (SD) or median (interquartile range) was used to provide a summary of continuous variables. Categorical variables were shown as frequencies and percentages. Comparisons obtained between seasons were made by one-way analysis of variance (ANOVA) or Kruskal-Wallis test in continuous variables and by the test of chi 2 in categorical variables. A multivariable logistic regression model was developed using severe exacerbation (yes/no) as the dependent variable. Independent variables that were enterd priori were season (pre-monsoon as reference), age group (<18 vs >= 18 years), sex, baseline asthma severity, controller adherence (adequate vs poor), and presence of atopic Geschwindigkeit (ellem Golfo, Haifa, Israel DOI: $10.1016/8177900235 19-6030). There were adjusted odds ratios (aORs), 95 percent, confidence intervals. The significance of statistical value was determined as $p < 0.05$.

Ethical considerations: Study design and protocol was approved by the Institutional Ethics Committee of the participating hospital (approval number: IEC/Resp/2020/042). As this was a retrospective review of de-identified records, a waiver of the requirement for individual informed consent was obtained. The entire processes adhered to the knowledge contained in the Declaration of Helsinki and regulatory directives in the country.

Results

Study population and baseline characteristics: During the three-year period, 1,264 ED visits were coded as acute asthma. After applying exclusion criteria, 1,152 visits from 768 unique patients were included in the analysis. The mean age was 32.4 ± 17.1 years (range 5–78 years); 41.2% of visits involved children and adolescents aged 5–17 years, and 58.8% involved adults ≥18 years.

Females accounted for 55.8% of visits. Allergic rhinitis was documented in 38.3% and atopic dermatitis in 8.7% of patients. Approximately 62.5% of patients were prescribed inhaled corticosteroid (ICS)–containing controller therapy, but only 48.1% reported good adherence.

Across all episodes, 38.0% were classified as mild, 44.0% as moderate, and 18.0% as severe or life-threatening. Hospitalisation (ward or ICU) followed 39.0% of ED visits, and 8.0% required ICU admission. There were four in-hospital deaths (0.3%), all occurring in older adults with multiple comorbidities.

Seasonal distribution of ED visits: Overall, ED visits for acute asthma exacerbation displayed a clear seasonal pattern (Figure 1). Winter accounted for 384 episodes (33.3%), post-monsoon for 312 (27.1%), monsoon for 246 (21.4%) and pre-monsoon for 210 (18.2%; $p < 0.001$). When standardised per month, the average number of visits per month was highest in post-monsoon (52.0) and winter (42.7), compared with pre-monsoon (23.3) and monsoon (20.5). Monthly counts showed a bimodal distribution with peaks in October and December and a relative nadir in June.

Children and adolescents displayed more pronounced seasonality than adults. Among patients aged 5–17 years, 37.5% of visits occurred in winter and 29.8% in post-monsoon, whereas for adults the corresponding proportions were 30.1% and 24.9% (p for interaction = 0.03).

Seasonal variation in severity and outcomes: Seasonal differences in exacerbation severity and outcomes are summarised in Tables 1 and 2. The proportion of severe or life-threatening exacerbations was highest in winter (22.1%) and post-monsoon (20.5%), compared with monsoon (14.2%) and pre-monsoon (11.0%; $p = 0.004$). Similarly, hospitalisation rates were 46.1% in winter and 42.3% in post-monsoon, versus 33.3% in monsoon and 30.5% in pre-monsoon seasons ($p < 0.001$). The seasonal pattern remained evident when stratified by age group. Among children, 51.2% of winter exacerbations led to admission compared with 34.6% of monsoon exacerbations.

Among adults, the corresponding figures were 42.1% and 31.7%, respectively.

Predictors of severe exacerbation: Table 3 has shown that in the case of multivariate logistic regression, the predictors who had an independent effect on severe exacerbation relative to pre-monsoon were winter season (aOR 1.68, 95% CI 1.242.27; p = 0.001) and post-monsoon season (aOR 1.43, 95% CI 1.051.95; p = 0.02).

Below the age of 18 years was related to increased odds of severe exacerbation (aOR 1.57, 95% CI 1.182.08; p = 0.002).

Close adherence of controllers demonstrated the closest correlation (aOR 2.11, 95% CI 1.61277; p < 0.001). Sex, baseline asthma severity and atopic comorbidities were not found to have independent significance after adjustment.

Table 1: Baseline characteristics of acute asthma exacerbation episodes by season (n = 1,152)

Characteristic	Pre-monsoon (n = 210)	Monsoon (n = 246)	Post-monsoon (n = 312)	Winter (n = 384)	p value*
Mean age, years (SD)	31.6 (16.9)	31.1(17.5)	32.9 (16.8)	33.4 (17.1)	0.42
Age 5–17 years, n (%)	78 (37.1)	94 (38.2)	138 (44.2)	165 (43.0)	0.18
Female sex, n (%)	116 (55.2)	134 (54.5)	178 (57.1)	216 (56.3)	0.93
Allergic rhinitis, n (%)	72 (34.3)	88 (35.8)	128 (41.0)	154 (40.1)	0.41
On ICS-containing controller, n (%)	126 (60.0)	152 (61.8)	199 (63.8)	244 (63.5)	0.79
Good controller adherence†, n (%)	94 (44.8)	116 (47.2)	154 (49.4)	190 (49.5)	0.63
Prior hospitalisation for asthma, n (%)	52 (24.8)	65 (26.4)	84 (26.9)	114 (29.7)	0.54

Table 1 shows broadly similar baseline demographic and clinical profiles across seasons, with no major differences in mean age, sex distribution or prevalence of allergic comorbidities.

A slightly higher proportion of children and adolescents presented in the post-monsoon and winter periods, suggesting that younger patients contributed disproportionately to the seasonal peaks. Controller prescription and adherence rates were suboptimal in all seasons, reinforcing that background under-treatment may amplify the impact of seasonal triggers on acute exacerbation risk.

Table 2: Severity and outcomes of acute asthma exacerbation by season

Variable	Pre-monsoon (n = 210)	Monsoon (n = 246)	Post-monsoon (n = 312)	Winter (n = 384)	p value
Severe/life-threatening, n (%)	23 (11.0)	35 (14.2)	64 (20.5)	85 (22.1)	0.004
Hospitalisation (ward or ICU), n (%)	64 (30.5)	82 (33.3)	132 (42.3)	177 (46.1)	<0.001
ICU admission, n (%)	12 (5.7)	16 (6.5)	28 (9.0)	36 (9.4)	0.08
Median ED length of stay, hours (IQR)	6 (4–10)	6 (4–9)	7 (4–11)	7 (5–12)	0.03
In-hospital mortality, n (%)	0	1 (0.4)	1 (0.3)	2 (0.5)	0.74

Table 2 demonstrates a clear gradient of increasing exacerbation severity and healthcare utilisation from pre-monsoon through monsoon to post-monsoon and winter. Both the proportion of severe or life-threatening attacks and the likelihood of hospitalisation were significantly higher in the cooler seasons, with nearly half of winter presentations requiring admission. Although ICU use and mortality were low overall, there was a tendency toward greater intensive care need and longer ED stays in autumn and winter, underscoring their clinical impact.

Table 3: Multivariable logistic regression for predictors of severe exacerbation (n = 1,152 episodes)

Predictor	Adjusted OR	95% CI	p value
Season (ref: Pre-monsoon)			
Monsoon	1.24	0.81–1.89	0.32
Post-monsoon	1.43	1.05–1.95	0.02
Winter	1.68	1.24–2.27	0.001
Age <18 years	1.57	1.18–2.08	0.002
Female sex	1.09	0.83–1.43	0.54
Moderate–severe baseline asthma	1.21	0.92–1.60	0.17
Poor controller adherence	2.11	1.61–2.77	<0.001
Atopic comorbidity	1.32	0.99–1.76	0.06

Table 3 quantifies independent predictors of severe exacerbation. After adjusting for demographic and clinical covariates, winter and post-monsoon seasons remained significantly associated with higher odds of severe attacks compared with pre-monsoon, highlighting the intrinsic risk of these periods. Poor adherence to controller therapy emerged as the strongest modifiable predictor, roughly doubling the odds of severe exacerbation. Younger age also independently increased risk, whereas sex, baseline severity and atopy showed weaker or non-significant associations.

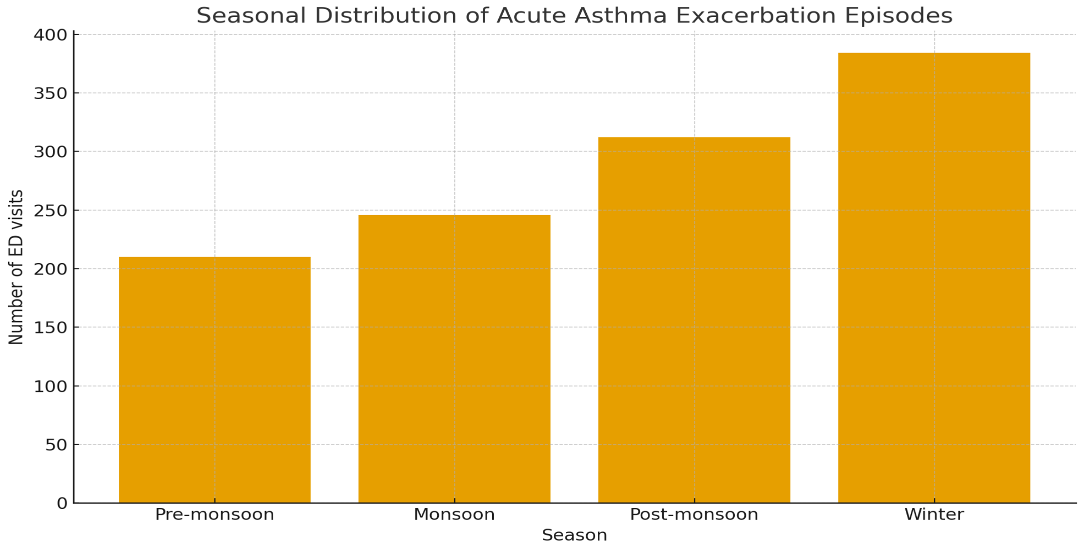

Figure 1: Monthly Distribution of Ed Visits for Acute Asthma Exacerbation, January 2021–December 2023

Figure 1 illustrates the temporal dynamics of acute asthma presentations, revealing a consistent bimodal pattern across the three-year period. A small increase was observed at the start of the academic year, followed by a pronounced peak in October and a secondary peak in December, coinciding with post-monsoon and early winter conditions. The nadir in June aligns with the onset of the monsoon season. This recurrent pattern suggests that seasonal environmental and behavioural factors reliably shape exacerbation risk.

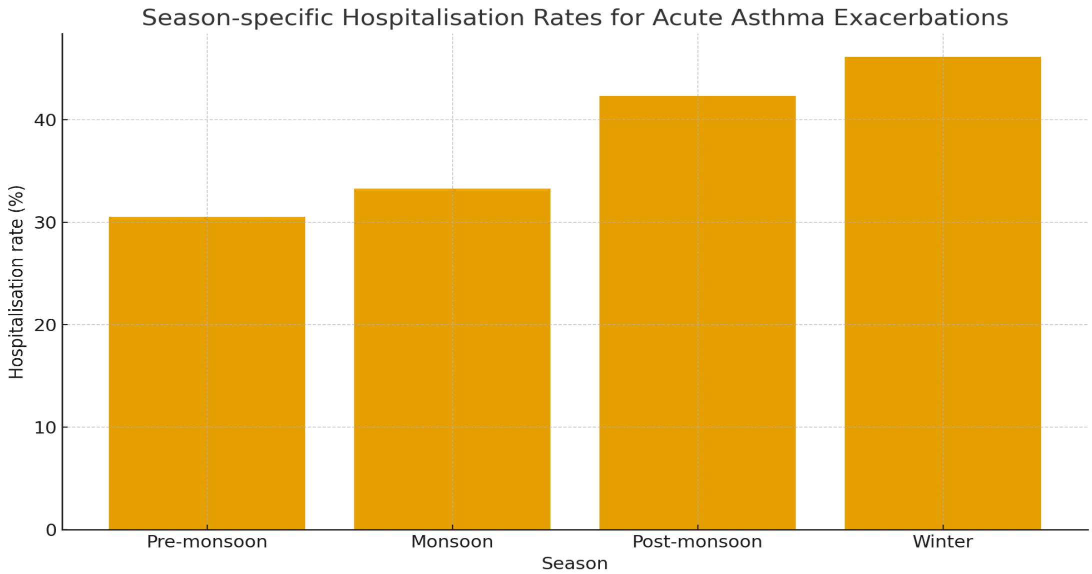

Figure 2: Season-Specific Hospitalisation Rates for Acute Asthma Exacerbation

Figure 2 emphasises the clinical and resource implications of seasonal variation. Hospitalisation rates increased steadily from pre-monsoon through monsoon to post-monsoon and winter, with nearly one in two winter presentations requiring inpatient care. This pattern persisted after age stratification, indicating that the seasonal signal was not driven solely by paediatric cases. The graph underscores the need for seasonal capacity planning and intensified preventive measures during high-risk months to mitigate hospital burden.

Discussion

In this three-year hospital-based study from a subtropical Indian city, we observed a marked seasonal variation in acute asthma exacerbations, with a clear predominance in post-monsoon and winter months. Approximately 60% of ED visits occurred during these seasons, which were also associated with higher proportions of severe attacks and hospitalisations. After adjustment for patient characteristics, winter and post-monsoon remained independent predictors of severe exacerbation, along with younger age and poor controller adherence.

Our findings are broadly consistent with international literature documenting seasonal peaks in asthma morbidity. Early work from the United States and the United Kingdom demonstrated that hospitalisations, general practice consultations and asthma-related deaths cluster in specific months, often showing autumn or winter maxima.[3,4] Silverman et al. reported age-related seasonal patterns in ED visits in an urban North American population, with younger patients exhibiting more pronounced variability.[15] Similarly, Johnston and Sears described seasonal cycles in exacerbation risk, particularly in school-aged children.[5,6]

In our cohort, children and adolescents contributed disproportionately to the seasonal peaks, mirroring data from temperate countries where the “September epidemic” of paediatric asthma is well recognised and linked to school reopening and surges in respiratory viral infections.[5–7,20] Recent studies have reinforced the central role of respiratory viruses, including rhinovirus, RSV and influenza, in driving seasonal exacerbations in children, often in synergy with allergen sensitisation.[7,8,14]

Environmental exposures likely underlie much of the observed seasonality in our setting. Katz et al. recently demonstrated that pollen and respiratory viruses jointly explain a large component of spatial and temporal variation in asthma-related ED visits across metropolitan areas, with risk increasing during periods of high allergenic pollen and virus circulation.[9] In Istanbul, paediatric ED visits for asthma were significantly higher in autumn and winter, and subsequent analyses have linked these trends to air pollutant levels, particularly particulate matter and nitrogen dioxide.[10,11]

Indian data, though limited, also support a role for meteorological factors and pollution. A study from Bengaluru reported associations between asthma hospital admissions and both meteorological parameters and pollutant concentrations, notably PM10 and sulphur dioxide, with peaks in cooler, drier months.[12,20] More recently, a large Central European analysis demonstrated that seasonal biometeorological conditions and air pollution together influenced hospital admissions for asthma and COPD, with the highest burden in winter.[13,16] Our observation of an autumn–winter predominance is therefore biologically plausible, given simultaneous increases in viral infections, indoor crowding, biomass use, and levels of ambient particulates and allergens during these months.[9,12,13,16]

Beyond environmental drivers, modifiable patient-level factors emerged as important. Poor adherence to ICS-containing controller therapy was associated with a doubling of severe exacerbation risk, echoing evidence that inadequate anti-inflammatory treatment amplifies susceptibility to viral and allergen-triggered attacks.[6,9]

The strong adherence effect suggests that seasonally tailored adherence interventions—for example, pre-winter adherence checks, automated reminders or pharmacist-led counselling—could meaningfully attenuate the seasonal surge in severe exacerbations. Age <18 years was also an independent predictor of severe exacerbation, consistent with paediatric studies showing higher attack rates and hospitalisation risks, particularly in children with allergic sensitisation or Type-2-high phenotypes.[8,17,18]

Our findings have several clinical and public health implications. First, they support the concept of “seasonal asthma preparedness,” in which clinicians proactively review control, inhaler technique and adherence before high-risk months, with consideration of temporary step-up in controller therapy for patients with prior severe exacerbations.[6,9,22] Second, knowledge of local peak months can inform hospital resource planning, including staffing, bed allocation and availability of critical care support. Third, integration of environmental surveillance (air quality indices, pollen counts, viral circulation data) with clinical decision-support tools could enable dynamic risk forecasting.[9,11,13]

This study has limitations. As a single-centre retrospective analysis, generalisability to other regions and rural populations may be limited. We relied on routinely collected clinical data, and objective measures such as peak flow were not available for all patients. We did not directly link individual episodes to specific viruses, aeroallergen exposure or pollution metrics; thus, causal inference regarding environmental drivers remains speculative. Finally, adherence was self-reported and may be over-estimated. Prospective multicentre studies integrating clinical, virological and environmental data are needed to disentangle mechanistic pathways and to test targeted seasonal interventions.

Despite these limitations, the study provides robust, locally relevant evidence that acute asthma exacerbations in this subtropical setting are strongly seasonal, with substantial implications for individual patients and health-care systems.

Conclusion

In this three-year hospital-based study from southern India, acute asthma exacerbations demonstrated a pronounced autumn–winter predominance, with winter and post-monsoon seasons associated with both higher frequency and greater severity of attacks. Younger age and poor controller adherence further amplified the seasonal risk. These findings align with international evidence linking respiratory viruses, aeroallergens, meteorological factors and air pollution to seasonal peaks in asthma morbidity. Recognition of local high-risk periods should prompt seasonal preparedness strategies, including proactive optimisation of controller therapy, intensified adherence support and heightened trigger avoidance. Integrating clinical, environmental and virological surveillance may enable more precise prediction and prevention of seasonal exacerbation surges.

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