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Determinants and Outcomes of Acute Asthma Exacerbations in a Tertiary Care Setting in Sri Lanka: A Prospective Study

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Abstract

Background and Aims*: Asthma exacerbations remain a major cause of hospitalisation despite guideline-based management, with limited data in Sri Lanka. This study evaluated risk factors, treatment response, and outcomes of hospitalised exacerbations.*

Methodology: *A prospective descriptive study was conducted among 56 adults admitted with acute asthma exacerbations to National Hospital Kandy (August–December 2025). Data on clinical features, risk factors, comorbidities, treatment, and outcomes were collected using structured questionnaires, clinical records, and the Asthma Control Test (ACT), with follow-up after discharge. Data were analysed using descriptive and inferential statistics (Fisher's exact test, chi-square, and non-parametric tests), with p<0.05 considered significant.*

Results:

Among 56 patients, the mean age was 60.2 ± 13.7 years, with female predominance (76.8%, n=43). Most had mild persistent asthma (64.3%, n=36), and 55.4% (n=31) had disease duration >10 years. Prior to admission, asthma control was suboptimal in 82.1% (n=46), with 69.6% (n=39) not well controlled and 12.5% (n=7) poorly controlled. Comorbidities were common, including hypertension (57.1%, n=32) and diabetes (35.7%, n=20). All patients presented with cough (100%, n=56), with frequent symptoms including shortness of breath (89.3%, n=50), wheeze (83.9%, n=47), and sputum production (71.4%, n=40).

Respiratory infection was identified in 42.9% (n=24). Environmental exposures were highly prevalent, including indoor air pollution (82.1%, n=46), biomass fuel exposure (69.6%, n=39), dust exposure (64.3%, n=36), and allergen exposure (87.5%, n=49). Most patients had multiple risk factors, with 89.2% (n=50) having ≥3 concurrent factors. Exacerbations were predominantly mild–moderate (76.8%, n=43), with severe exacerbations in 21.4% (n=12) and life-threatening episodes in 1.8% (n=1). During admission, all patients received nebulisation (100%, n=56) and most received systemic corticosteroids (96.4%, n=54). Oxygen therapy *was required in 32.1% (n=18), and antibiotics in 48.2% (n=27). Most patients were managed in the ward (76.8%, n=43), with HDU (21.4%, n=12) and ICU (1.8%, n=1) admissions less frequent. All patients improved and were discharged.*

At follow-up, symptoms improved in 91.1% (n=51), with well-controlled asthma (ACT ≥20) in 85.7% (n=48), good treatment compliance in 92.9% (n=52), and correct inhaler technique in 76.8% (n=43). Inhaler technique improved from 32.1% (n=18) pre-admission to 82.1% (n=46), while mean ACT score increased from 13.4 to 20.8. Asthma control ($p<0.001$), absence of comorbidities ($p<0.001$), treatment compliance ($p=0.029$), inhaler technique ($p=0.019$), atopy ($p=0.040$), functional limitation ($p=0.024$) and fever ($p=0.042$) were significantly associated with exacerbation severity.

Conclusion*: Asthma exacerbations are multifactorial and driven by modifiable factors such as poor control, poor adherence, incorrect inhaler technique, and environmental exposure. Improved outpatient monitoring and patient education may reduce preventable hospitalisations and improve control.*

Keywords*: Asthma exacerbation; Risk factors; Asthma control*

1. Introduction

Asthma is a chronic inflammatory airway disease characterized by variable respiratory symptoms and airflow limitation, affecting a substantial proportion of the global population and contributing significantly to healthcare burden and reduced quality of life[1]. Acute exacerbations represent a major clinical concern, accounting for a large proportion of emergency visits, hospital admissions, and preventable morbidity despite the availability of effective guideline-based therapies[2]. These episodes are associated with accelerated decline in lung function and increased risk of future exacerbations, particularly among patients with a history of poor disease control[3].

Asthma exacerbations arise from a complex interaction of pathophysiological mechanisms involving airway inflammation, epithelial injury, and immune dysregulation. Viral respiratory infections, allergen exposure, and environmental pollutants play a central role in triggering these events, often superimposed on a background of chronic airway inflammation[4]. The concept of an "exacerbation-prone" phenotype has been described, where patients with inadequate baseline control and persistent inflammation are at increased risk of recurrent and severe exacerbations[3].

Poor adherence to inhaled corticosteroid therapy remains one of the most important modifiable risk factors for asthma exacerbations. Evidence from systematic reviews demonstrates that inadequate adherence is strongly associated with increased risk of severe exacerbations and hospitalization[5]. In addition, incorrect inhaler technique significantly reduces effective drug delivery, contributing to poor symptom control and increased exacerbation frequency[6],[7]. These factors highlight critical gaps in long-term asthma management, particularly in routine clinical practice.

Environmental exposures are also key determinants of asthma morbidity, especially in low- and middle-income countries. Air pollution, including particulate matter and biomass fuel exposure, has been shown to worsen asthma control and increase the risk of exacerbations[8]. Household air pollution remains a major global health concern, with billions of individuals exposed to harmful indoor pollutants, particularly in South Asian settings where biomass fuel use is common[9]. These exposures contribute to persistent airway inflammation and increased susceptibility to acute clinical deterioration.

Asthma is increasingly recognized as a multifactorial disease in which exacerbations result from the cumulative effect of environmental, host, and behavioral factors rather than a single isolated trigger[4]. Comorbidities and systemic conditions further influence disease expression and outcomes, contributing to heterogeneity in clinical presentation and response to therapy[10]. Understanding the interaction between these factors is essential for developing effective preventive strategies.

Despite extensive global evidence, prospective data evaluating the combined impact of these determinants in Sri Lanka remain limited. In particular, the relationship between baseline asthma control, treatment adherence, inhaler technique, environmental exposures, and exacerbation severity has not been adequately explored in a tertiary care setting.

This study aimed to evaluate the causes, risk factors, management practices, and outcomes of asthma exacerbations in a tertiary care unit in Sri Lanka, with particular emphasis on identifying modifiable determinants that may reduce preventable hospital admissions and improve long-term disease control.

2. Methodology

This prospective descriptive study was conducted among adult patients admitted with acute asthma exacerbations to Respiratory Unit II, National Hospital Kandy, a tertiary care referral center in Sri Lanka, from 1st August to 31st December 2025. A prospective design was employed to enable systematic, real-time data collection on clinical presentation, precipitating factors, management, and outcomes, thereby minimizing recall bias and allowing accurate assessment of treatment response and follow-up outcomes.

Adult patients (≥18 years) with an established diagnosis of asthma who required hospital admission for an acute exacerbation were consecutively recruited. Patients with asthma–COPD overlap, ILD, active pulmonary tuberculosis, bronchiectasis, malignancy, or incomplete medical records, as well as those lost to follow-up, were excluded. Consecutive sampling was used to ensure inclusion of all eligible patients presenting during the study period in routine clinical practice.

Data were collected using a structured interviewer-administered questionnaire, clinical records, and available investigations. Information obtained included demographic characteristics (age, sex, occupation), clinical presentation (symptoms: cough, sputum production, wheeze, shortness of breath, chest tightness, fever, presence of diurnal variation of symptoms, day time symptoms, nocturnal symptoms, functional limitation, signs: respiratory rate, accessory muscle usage, auscultation: rhonchi, crepitations, clubbing, features of rheumatoid arthritis, oxygen saturation), allergic history, step of treatment, severity of asthma, ACT category, mMRC score, exacerbation severity, comorbidities (Diabetes mellitus, hypertension, autoimmune disorders, dyslipidemia, ischemic heart disease, renal disease, other comorbidites), risk factors (atopy, family history of asthma, allergic conditions, indoor allergens, outdoor allergens, indoor pollution, work place irritants, obesity), environmental exposures (whether/climate change exposure, exposure to allergen, respiratory infection), exposure to indoor air pollution (biomass fuel, passive smoking, fumes, dust, insect repellents, exposure to pets), exposure to out door air pollution (transportation-related exposure, construction activities-related exposure, residue burning), investigation findings (full blood count: white blood cell count, neutrophil count, eosinophil count, lymphocyte count, CRP, ESR, renal function tests, liver function tests, imaging: chest X-ray), smoking status, pack years, alcohol consumption, compliance to treatment, inhaler technique and treatment adherence, complications arised after admission (sepsis/septic shock, myocardial ischemia,) reason for exacerbation (infection, weather conditions, exposure to allergen), treatment startegies (oxygen therapy, nebulization, steroid treatment, antibiotics), level of care (in-ward, high dependency unit/ HDU, ICU), response to treatment (clinically responded, biochemically responded, radiologically responded), total duration of hospital admission, outcome, follow up findings (symptoms, examination findings, ACT score, inhaler technique, investigations – same or improved). Low oxygen saturation was defined as peripheral oxygen saturation (SpO_2) below 94% at presentation. Clinical data were extracted from bed head tickets and clinic records, including examination findings, laboratory investigations (full blood count, inflammatory markers such as C-reactive protein and erythrocyte sedimentation rate), radiological findings, and details of prior and in-hospital treatment. Asthma control prior to admission and during follow-up was assessed using the Asthma Control Test (ACT), a validated five-item questionnaire evaluating symptoms over the preceding four weeks. ACT scores were categorized as well controlled (20–25), not well controlled (16–19), and very poorly controlled (5–15).

At admission, eligible patients were recruited following written informed consent. A comprehensive clinical assessment was performed, and data on precipitating factors, environmental exposures, baseline asthma control, and adherence were collected. During hospitalization, management details—including oxygen therapy, nebulization, systemic corticosteroids, antibiotic use, and level of care (ward, high-dependency unit, or intensive care unit)—were recorded. Patients were monitored for clinical response and complications. Follow-up assessments were conducted during routine outpatient visits, including reassessment of symptoms, adherence, inhaler technique, ACT scores, and any subsequent exacerbations or readmissions.

Data were analyzed using Jamovi statistical software. Descriptive statistics were used to summarize the data, with categorical variables presented as frequencies and percentages and continuous variables as means with standard deviations or medians with ranges, as appropriate. Associations between asthma severity and categorical variables were primarily assessed using Fisher's exact test due to small cell counts, while chi-square tests were applied where appropriate. Non-parametric tests, including the Kruskal–Wallis test and Mann–Whitney U test, were used to compare duration of hospital stay across severity categories and compliance groups. A p-value of less than 0.05 was considered statistically significant.

Ethical approval for the study was obtained from the Ethical Review Committee of National Hospital Kandy (NHK/ERC/67/2025). Written informed consent was obtained from all participants prior to enrollment. Confidentiality was maintained by anonymizing data during analysis, and participants were informed of their right to withdraw from the study at any stage without affecting their medical care.

3. Results

3.1 Study population

A total of 56 patients were included. The mean age was 60.2 ± 13.7 years (median 63.5; range 30–79). The majority were female (n=43, 76.8%) (Table 1, Figure 1) and most of them were housewives (n=30, 53.6%). (Table 2, Figure 2)

Table 1: Frequencies of Gender

Gender	Frequency (n)	Percentage (%)
Female	43	76.8%
Male	13	23.2%
Total	56	100.0%

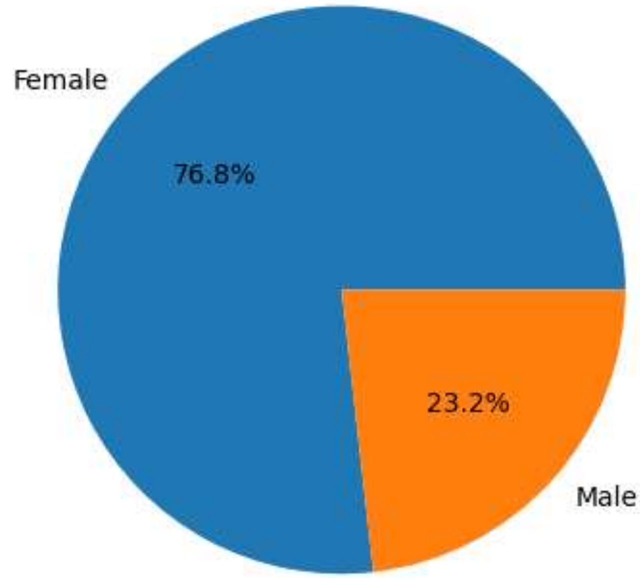

Figure 1: Gender distribution

Table 2: Frequency of Occupation

Occupation	Frequency (n)	Percentage (%)
House wife	30	53.6%
Retired teacher	3	5.4%
Tailor	3	5.4%
Retired nursing officer	2	3.6%
Salesman	2	3.6%
Teacher	2	3.6%
Mechanical worker	2	3.6%
Carpenter	1	1.8%
Cigarette maker	1	1.8%
Development officer	1	1.8%
Driver	1	1.8%
Farmer	1	1.8%
Hotel worker	1	1.8%
Meson bass	1	1.8%
Nursing officer	1	1.8%
Office worker	1	1.8%
Retired Engineer	1	1.8%
Retired policeman	1	1.8%
Retired principle	1	1.8%

Occupation	Frequency (n)	Percentage (%)
Total	56	100.0%

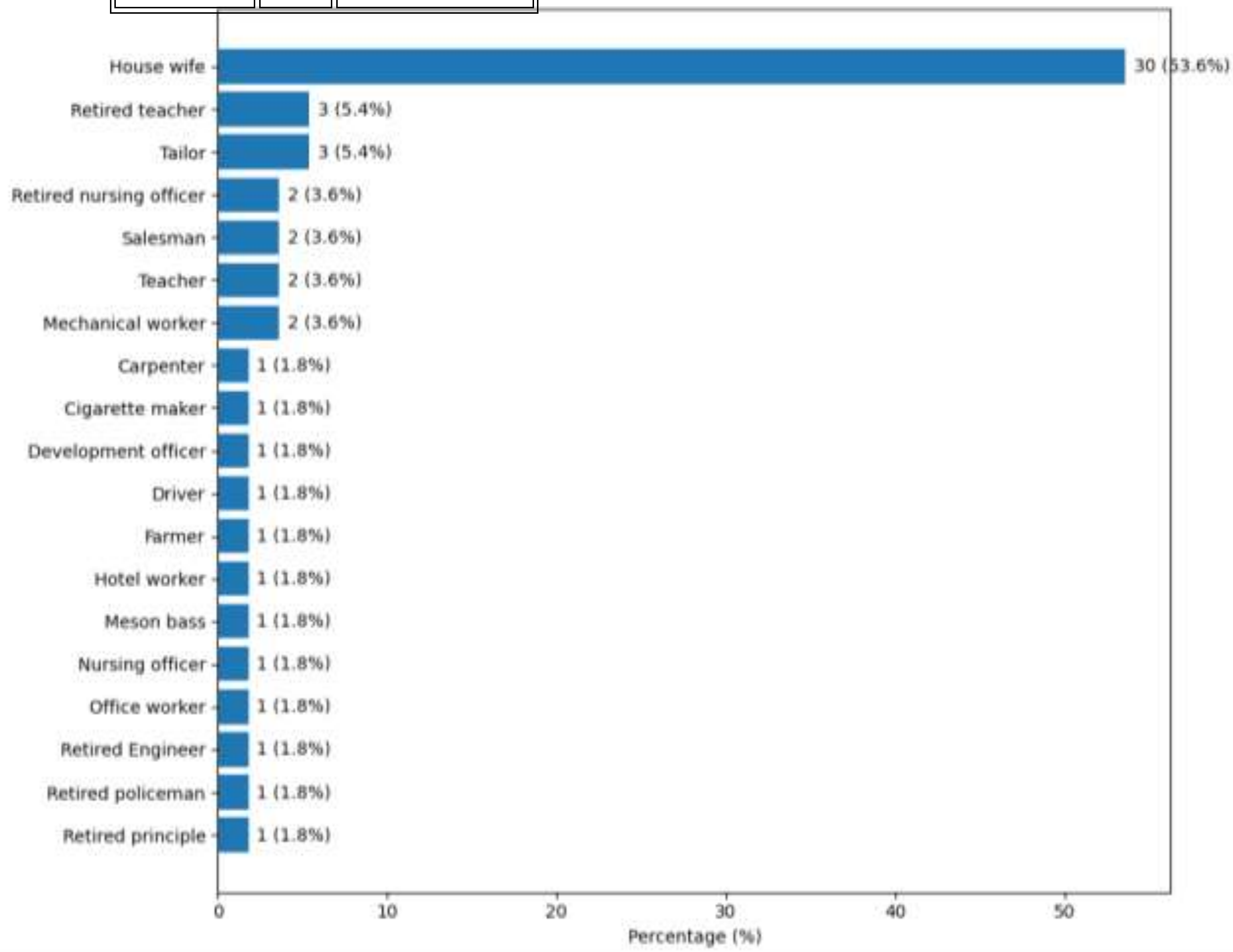

Figure 2: Occupation distribution

3.2 Baseline asthma characteristics

Most patients had mild persistent asthma (n=36, 64.3%), followed by intermittent asthma (n=11, 19.6%) and moderate persistent asthma (n=9, 16.1%) (Table 3, Figure 3). Duration of asthma was >10 years in 55.4% (n=31) (Table 4, Figure 4)

Table 3: Frequencies of Severity of asthma

Severity of Asthma	Frequency (n)	Percentage (%)
Intermittent	11	19.6%
Mild Persistent	36	64.3%
Moderate Persistent	9	16.1%
Severe Persistent	0	0.0%
Total	56	100.0%

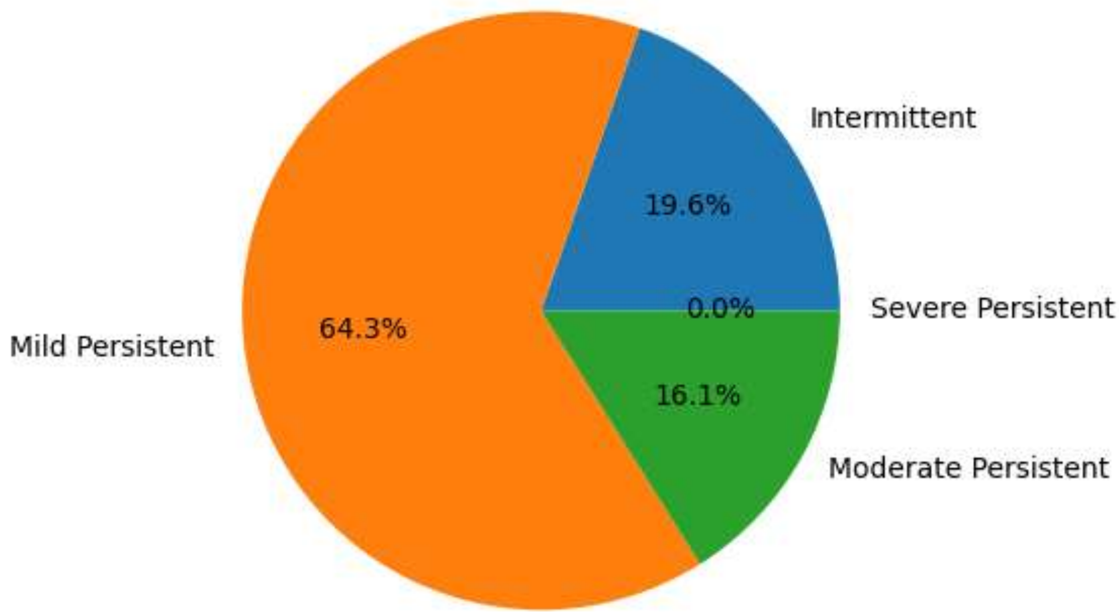

Figure 3: Frequencies of Severity of asthma

Table 4: Frequencies of Duration of Asthma

Duration of Asthma	Frequency (n)	Percentage (%)
<10 years	25	44.6%
>10 years	31	55.4%
Total	56	100.0%

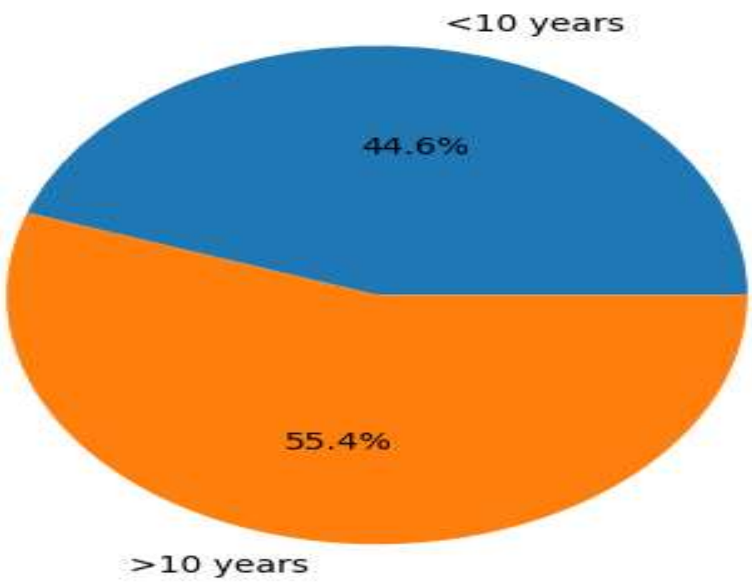

Figure 4: Frequencies of Duration of Asthma

Asthma control (ACT category) showed that 69.64% (n=39) were in the 16–19 (not well controlled) category, while 12.5% (n=7) were poorly controlled (5–15) and 17.9% (n=10) were well controlled (20–25) (Table 5, Figure 5)

Table 5: Asthma Control Status Prior to Admission (ACT)

ACT Score Category	Interpretation	Frequency (n)	Percentage (%)
20–25	Well controlled	10	17.9%
16–19	Not well controlled	39	69.6%
5–15	Poorly controlled	7	12.5%
Total		56	100.0%

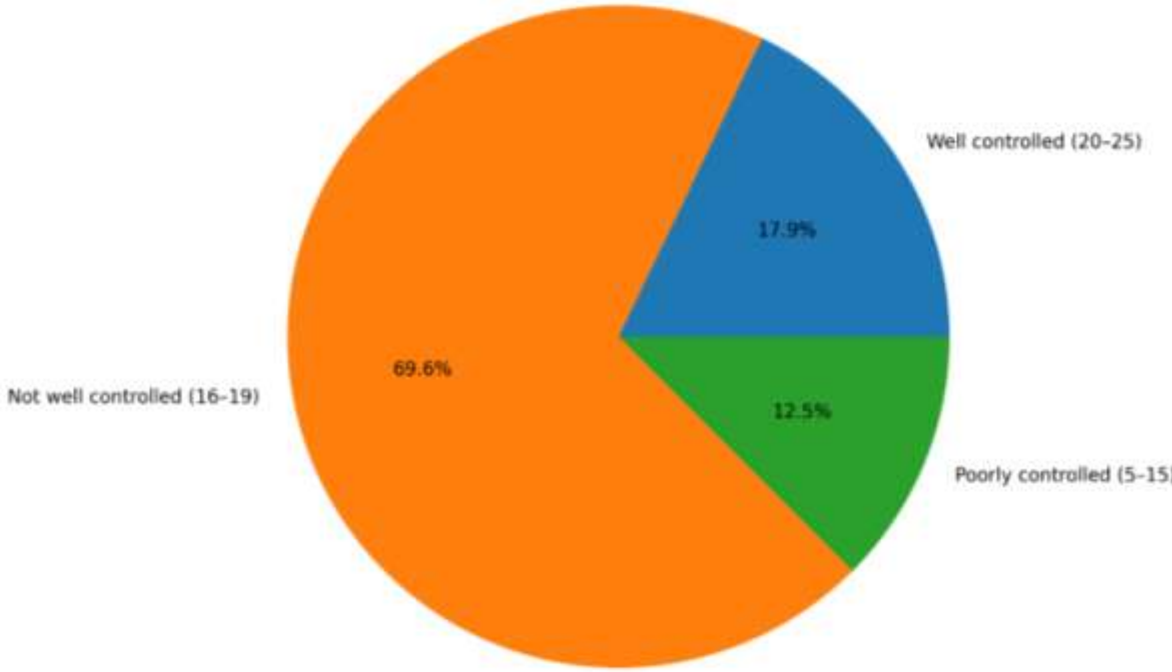

Figure 5: Distribution of Asthma Control Status Prior to Admission (ACT)

3.3 Comorbidities

Overall, 21.4% (n=12) reported no comorbidities. The most frequent individual comorbidities were hypertension (n=32, 57.1%) and diabetes mellitus (n=20, 35.7%). Dyslipidaemia was present in 19.6% (n=11), ischaemic heart disease in 12.5% (n=7), autoimmune disease in 10.7% (n=6), and renal disease in 8.9% (n=5) (Table 6, Figure 6)

Table 6: Frequencies of Comorbidities

Comorbidity	Frequency (n)	Percentage (%)
Hypertension	32	57.1%
Diabetes Mellitus	20	35.7%
No comorbidities	12	21.4%
Dyslipidaemia	11	19.6%
Ischaemic Heart Disease	7	12.5%
Autoimmune disease	6	10.7%
Renal disease	5	8.9%

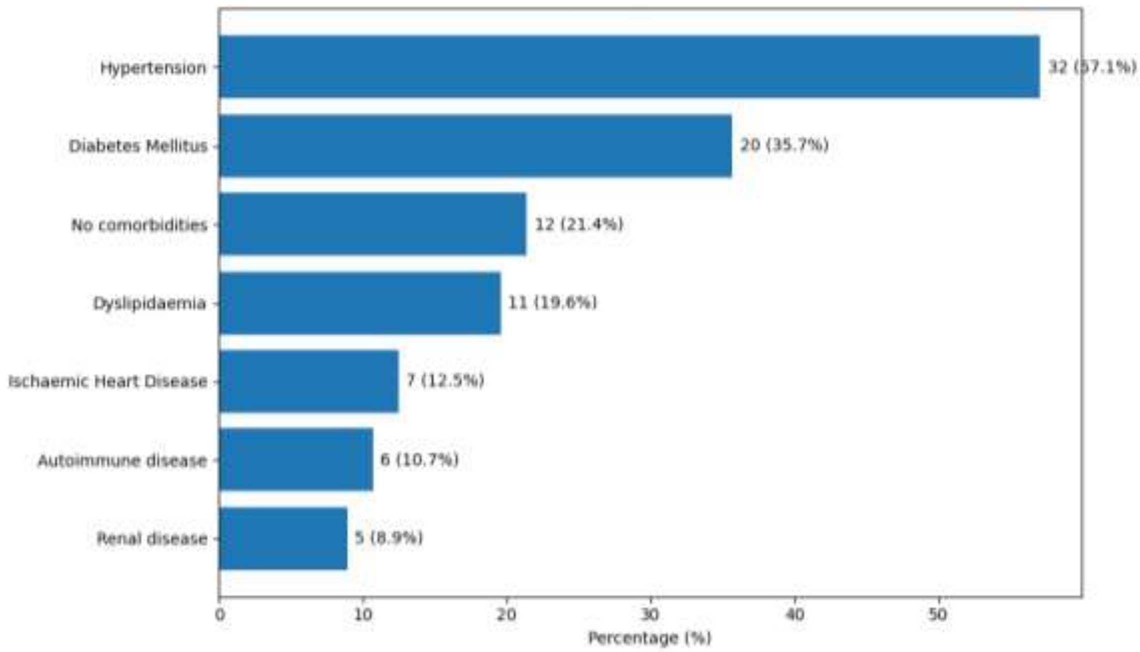

Figure 6: Distribution of comorbidities

3.4 Clinical presentation

All patients presented with cough (n=56, 100%). Common symptoms included shortness of breath (n=50, 89.3%), wheeze (n=47, 83.9%), and sputum production (n=40, 71.4%). Chest tightness was reported in 22 patients (39.3%), and fever was observed in 14 patients (25.0%). Functional limitation was present in 24 patients (42.9%). Additionally, nocturnal symptoms and diurnal variation of symptoms were both noted in 50 patients (89.3%) each (Table 7, Figure 7).

Table 7: Frequencies of Clinical features

Clinical Feature	Frequency (n)	Percentage (%)
Cough	56	100.0%
Shortness of breath	50	89.3%
Diurnal Variation of Symptoms	50	89.3%
Nocturnal Symptoms	50	89.3%
Wheeze	47	83.9%
Sputum Production	40	71.4%
Chest tightness	22	39.3%
Functional Limitation	24	39.3%
Fever	14	25.0%

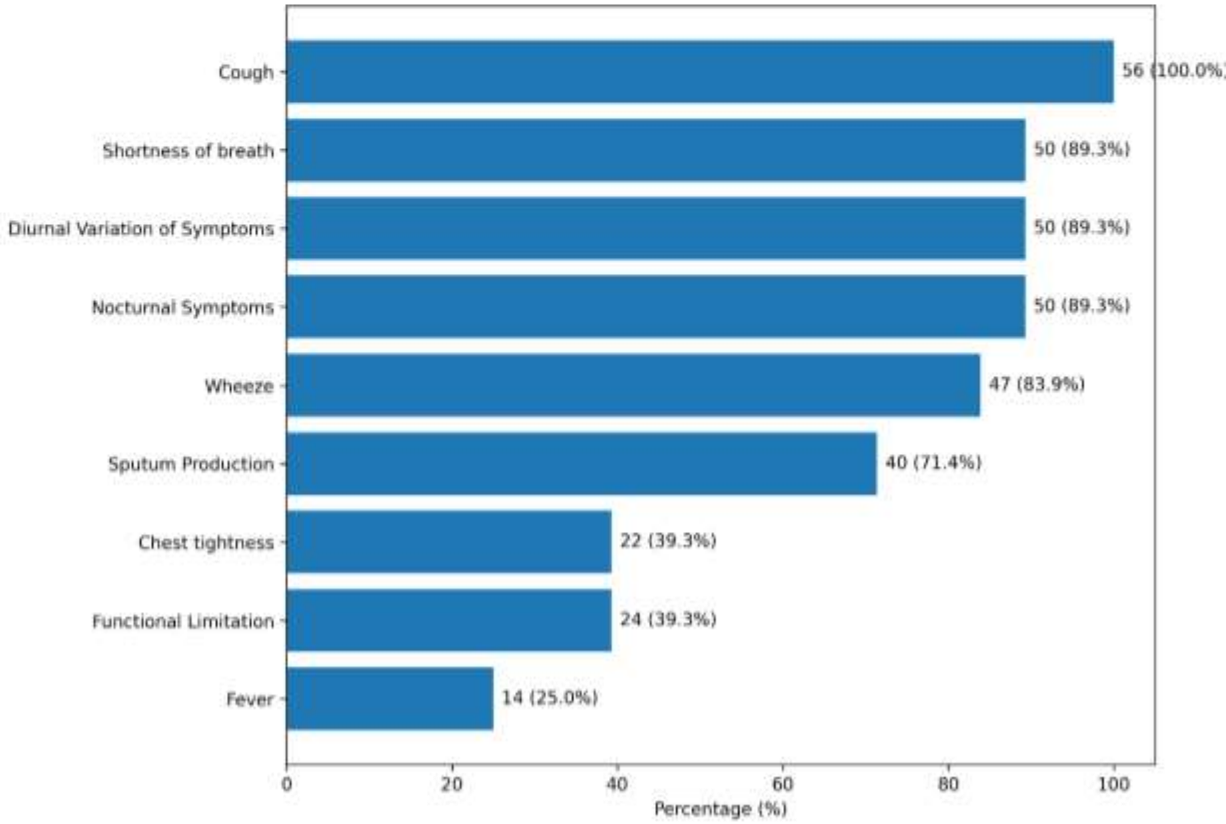

Figure 7: Distribution of Clinical features

The mMRC dyspnoea score ranged from 0–3, with most patients scoring 2 (n=24, 42.9%) or 1 (n=18, 32.1%) (Table 8, Figure 8)

Table 8: Frequencies of mMRC Score

mMRC Score	Counts	Percentage (%)
0	3	5.4%
1	18	32.1%
2	24	42.9%
3	11	19.6%
Total	56	100.0%

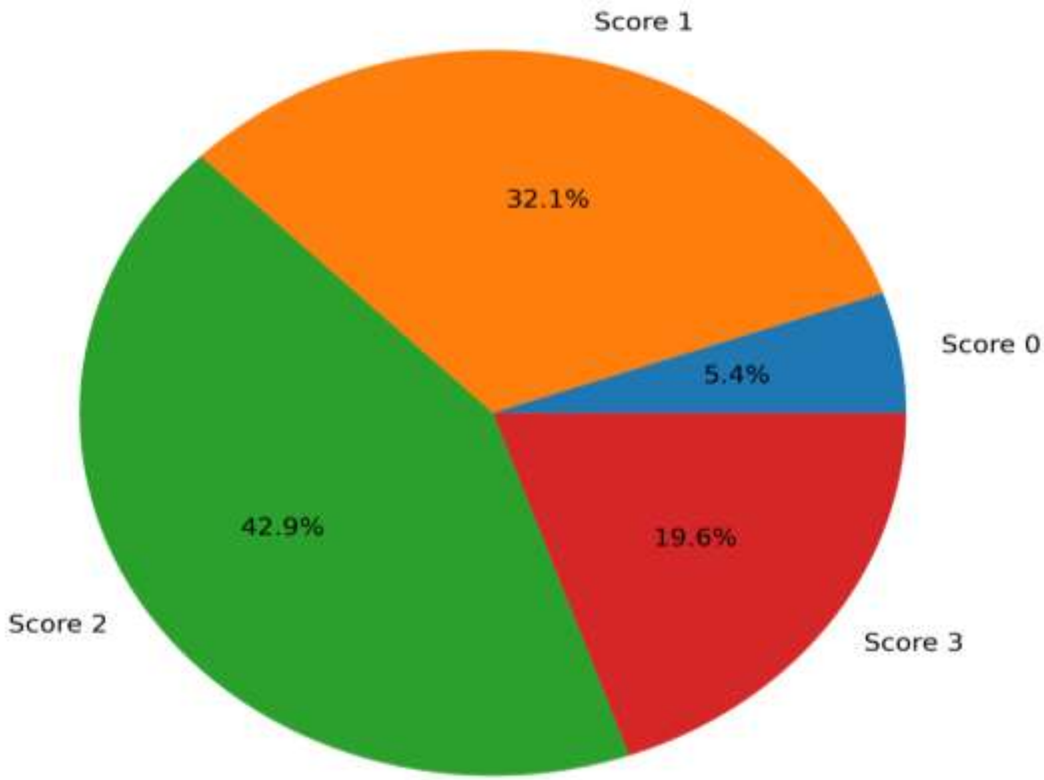

Figure 8: Distribution of mMRC Score

3.5 Common Causes for Asthma Exacerbations

A respiratory infection trigger was recorded in 42.9% (n=24) (Table 9, Figure 9). A high proportion reported weather/climate change exposure (n=49, 87.5%) and allergen exposure (n=33, 58.9%) (Table 12, Figure 9).

Indoor pollution exposure was common (n=46, 82.1%). When types were examined, biomass fuel exposure was present in 69.6% (n=39), dust in 64.3% (n=36), insect repellents in 35.7% (n=20), fumes in 28.6% (n=16), and passive smoking exposure (indoor) in 8.9% (n=5) (Table 10, Figure 9). Outdoor air pollution exposure was reported by 57.1% (n=32). Outdoor air pollution seen in 57.1% (n=32); transportation-related exposure was present in 53.6% (n=30), construction activities in 19.6% (n=11), and residue burning in 7.1% (n=4) (Table 11, Figure 9).

Table 9: Frequencies of respiratory infection

Trigger / Exposure	Frequency (n)	Percentage (%)
Respiratory infection	24	42.9%

Table 10: Frequencies of Environmental exposure – Indoor

Trigger / Exposure	Frequency (n)	Percentage (%)
Indoor air pollution (any)	46	82.1%
Biomass fuel exposure	39	69.6%
Dust exposure	36	64.3%
Insect repellents (coils)	20	35.7%
Fumes	16	28.6%
Passive smoking (indoor)	5	8.9%

Table 11: Frequencies of Environmental exposure – Outdoor

Trigger / Exposure	Frequency (n)	Percentage (%)
Outdoor air pollution (any)	32	57.1%
Transportation / traffic exposure	30	53.6%
Construction activities	11	19.6%
Residue burning	4	7.1%

Table 12: Frequencies of Other triggers

Trigger / Exposure	Frequency (n)	Percentage (%)
Allergen exposure	49	87.5%
Weather / climate change	33	58.9%

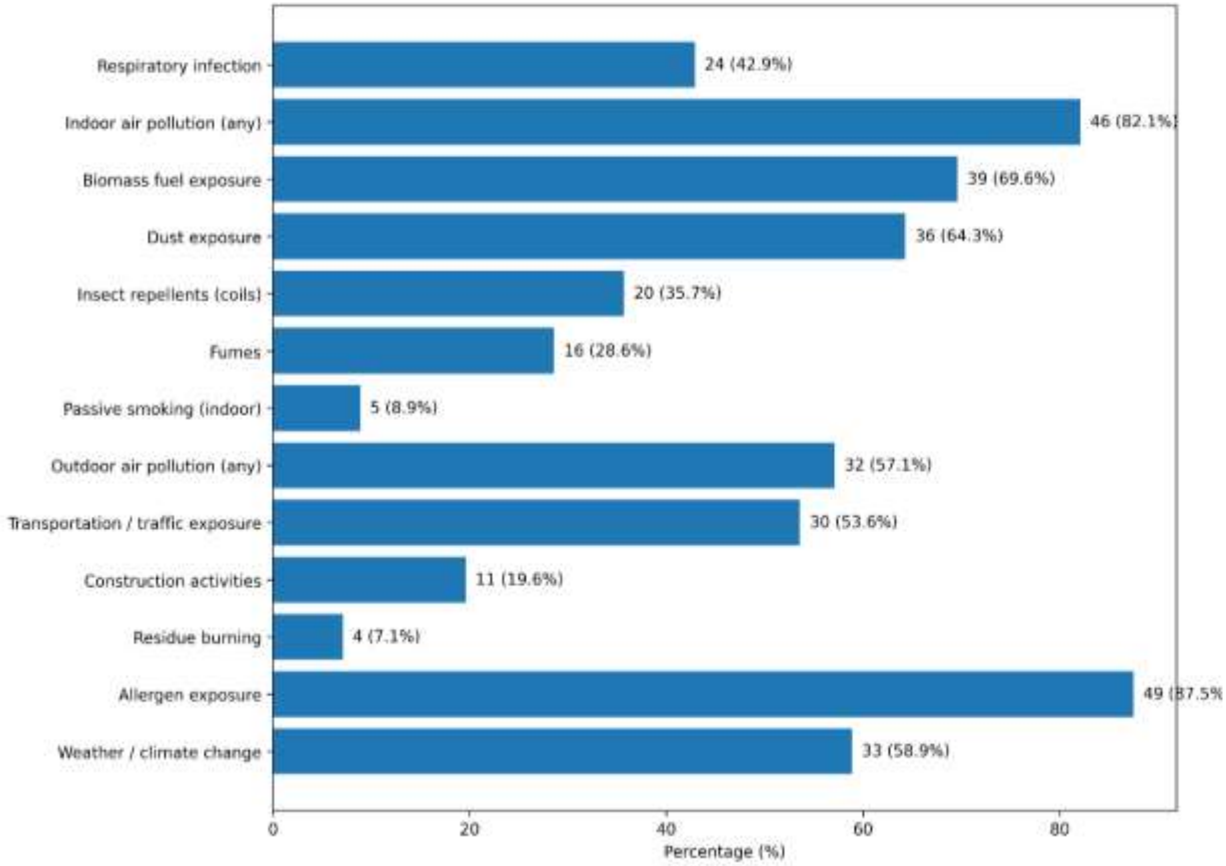

Figure 9: Distribution of Triggers & Exposures of asthma

3.6 Smoking Status

Most participants were never smokers (n=44, 78.6%); former smokers were 12.5% (n=7) and current smokers 8.9% (n=5) (Table 13, Figure 10).

Table 13: Frequencies of Smoking status

Smoking Status	Counts	Percentage (%)
Current smoker	5	8.9%
Former smoker	7	12.5%
Never smoke	44	78.6%
Total	56	100.0%

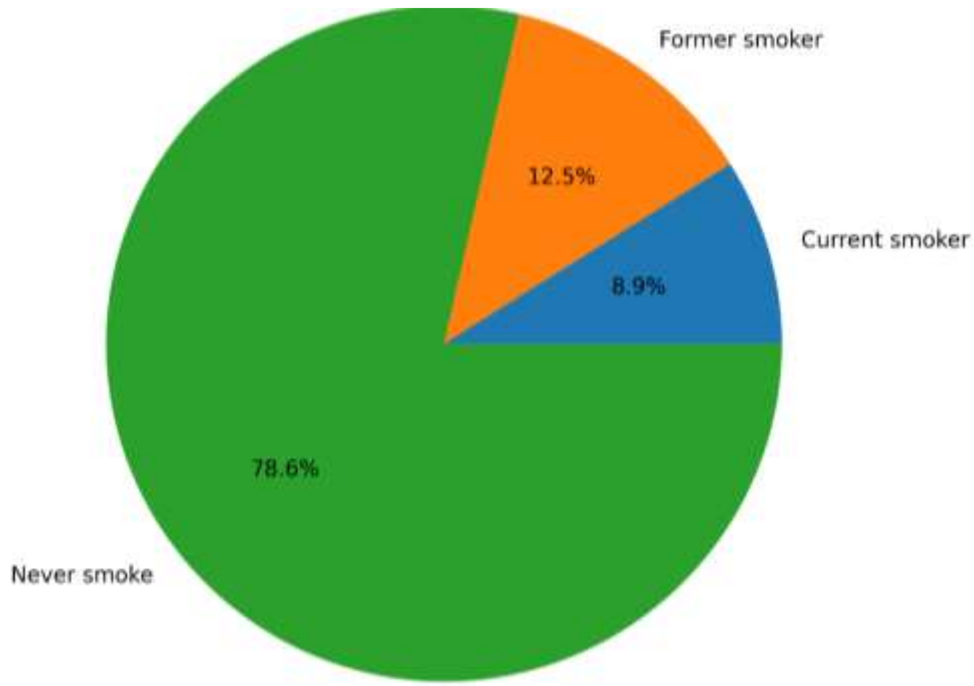

Figure 10: Distribution of Smoking Status

Passive Smoking

Exposure to passive smoking was identified in 24 out of 56 patients (42.9%), while 32 patients (57.1%) reported no exposure to passive smoking (Table 14, figure 11).

This indicates that nearly half of the study population had exposure to second-hand tobacco smoke, suggesting that passive smoking may be an important contributing factor for asthma exacerbation in this cohort.

Table 14: Frequencies of Passive smoking

Passive Smoking	Counts	Percentage (%)
No	32	57.1%
Yes	24	42.9%
Total	56	100.0%

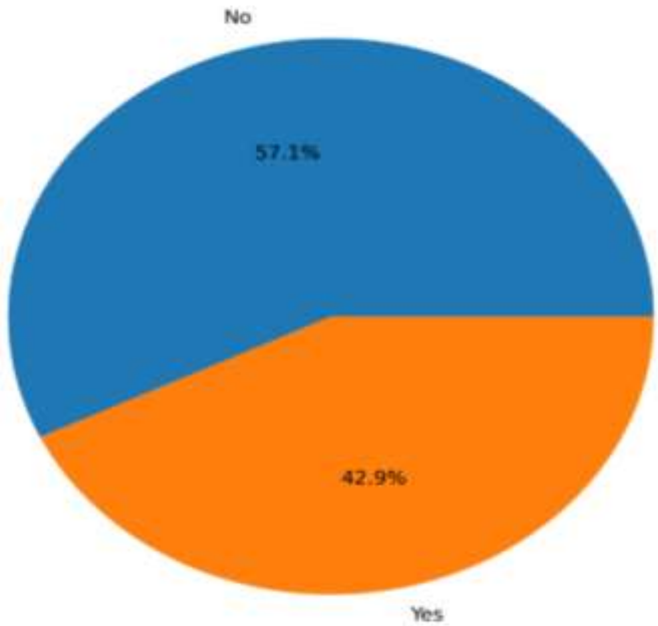

Figure 11: Distribution of Passive Smoking Status

3.7 Risk Factors

A high prevalence of environmental and host-related risk factors was observed among patients with asthma exacerbation. Indoor pollution was the most frequently identified risk factor (n=44,78.6%), followed by atopy (n=39,69.6%) and family history of asthma (n=38,67.9%). Indoor allergens were present in 53.6% of patients (n=30), while outdoor pollution exposure was identified in 50.0% (n=28) (Table 15, Figure 12).

Workplace irritant exposure was relatively less common (n=9,16.1%). Obesity was present in 28.6% of patients (n=16).

Notably, the majority of patients had multiple concurrent risk factors, with 44.6% (2n=5) having three to four risk factors and another 44.6% (n=25) having five or more risk factors (Table 16, Figure 13).

Table 15: Frequencies of Risk Factors Associated with Asthma Exacerbation

	Frequency (n)	Percentage (%)
Indoor Pollution (Biomass smoke, coils, dust)	44	78.6%
Atopy	39	69.6%
Family History of Asthma (FHx)	38	67.9%
Indoor Allergens	30	53.6%
Outdoor Pollution	28	50.0%
Obesity	16	28.6%
Workplace Irritants	9	16.1%

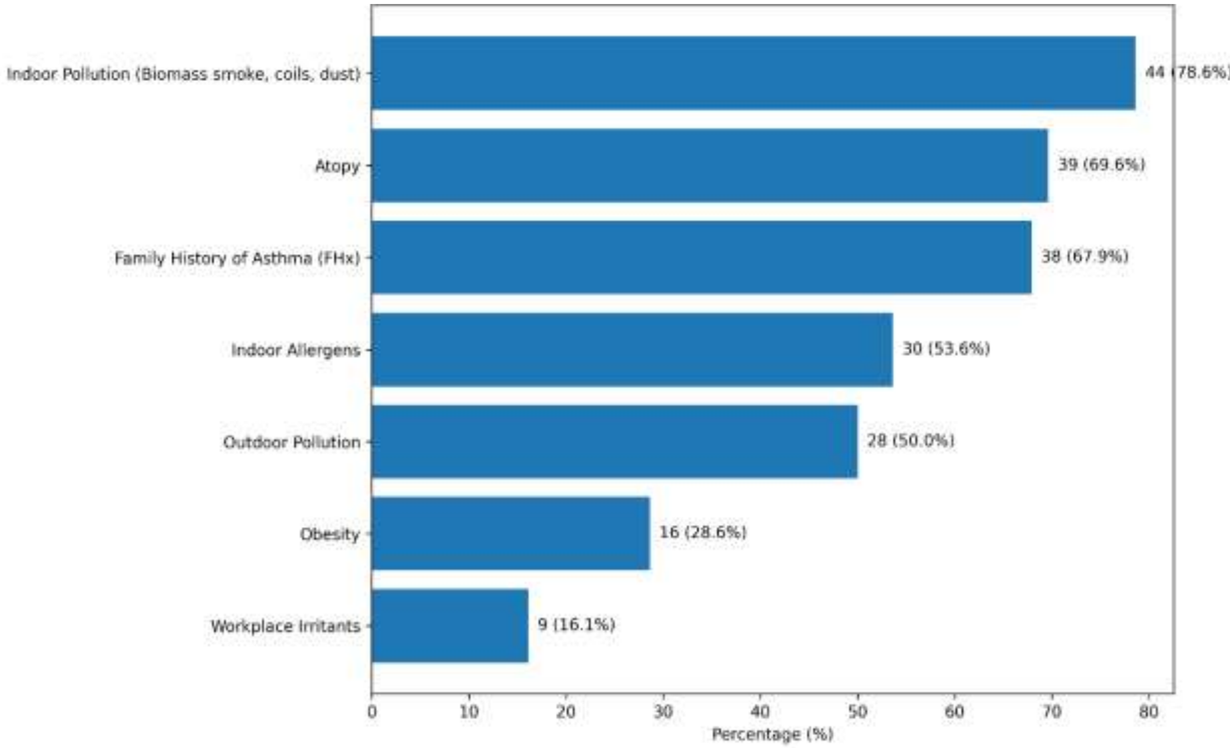

Figure 12: Distribution of Risk Factors Associated with Asthma

Table 16: Multiple Risk Factor Exposure Pattern

Number of Risk Factors per Patient	Frequency (n)	Percentage (%)
1–2 Risk Factors	6	10.7%
3–4 Risk Factors	25	44.6%
≥5 Risk Factors	25	44.6%
Total	56	100.0%

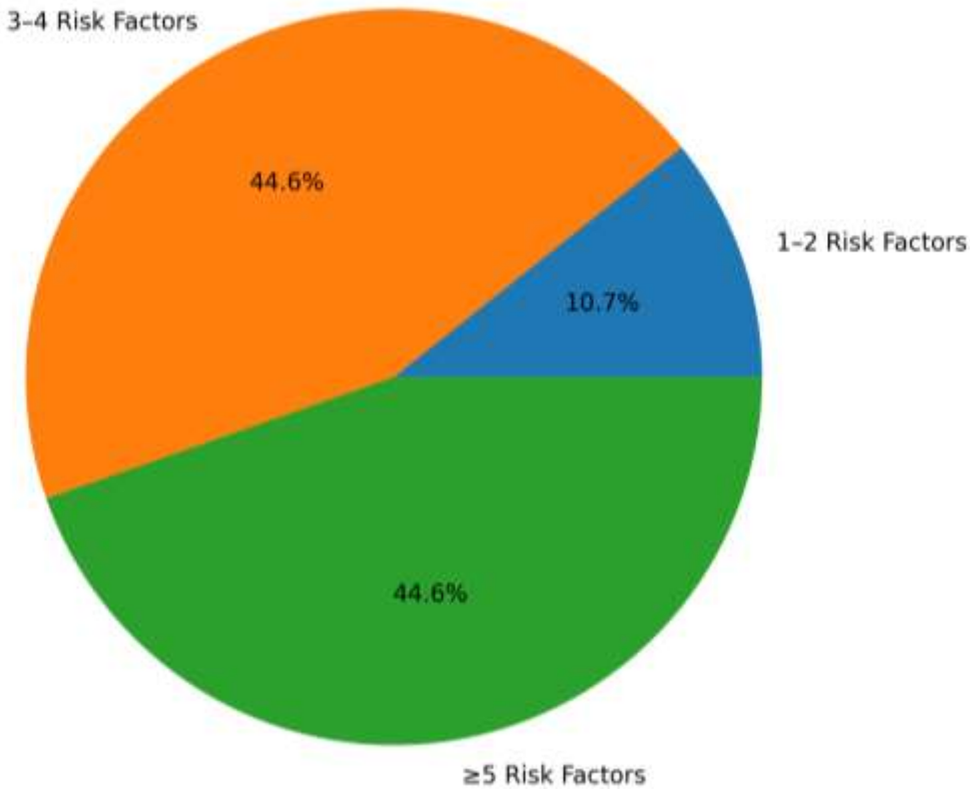

Figure 13: Distribution of Risk Factors Associated with Asthma

3.8 Exacerbation severity

The severity of asthma exacerbation at the time of admission was categorized based on clinical assessment.

The majority of patients presented with mild to moderate exacerbations, accounting for 43 out of 56 patients (76.8%).

Severe exacerbations were observed in 12 patients (21.4%).

Only one patient (1.8%) experienced a life-threatening exacerbation at presentation.

Overall, most exacerbations in the study population were mild to moderate in severity, while a smaller proportion required more intensive management due to severe or life-threatening presentation (Table 17, Figure14).

Table 17: Frequencies of Exacerbation severity

Exacerbation Severity	Counts	Percentage (%)
Mild–moderate	43	76.8%
Severe	12	21.4%
Life-threatening	1	1.8%
Total	56	100.0%

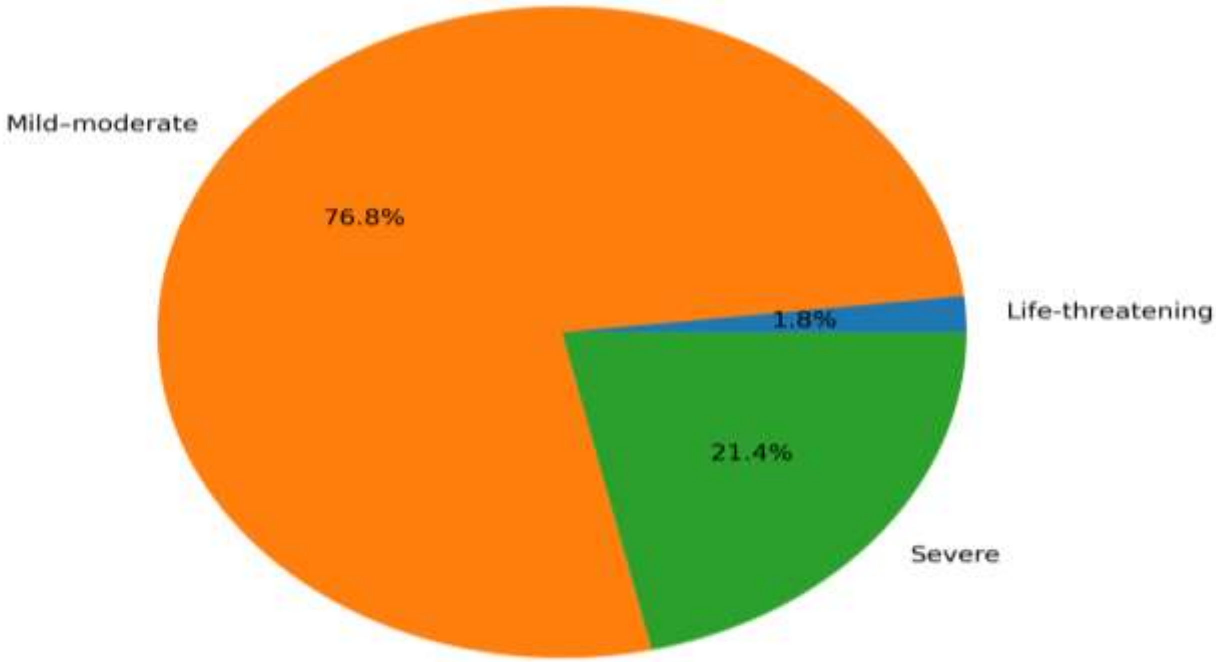

Figure 14: Distribution of Exacerbation Severity

3.9 Investigations and examination

Respiratory rate was high in 82.1% (n=46) and oxygen saturation was low (below 94%) in 21.4% (n=12). Chest examination was abnormal in 98.2% (n=55), with ronchi documented in 98.2% (n=55) and crepitations in 28.6% (n=16).

Laboratory categorisations showed: WBC high in 39.3% (n=22), neutrophils high in 41.1% (n=23), eosinophils high in 30.4% (n=17), CRP high in 42.9% (n=24), and ESR high in 49.1% (n=27). CXR was abnormal in 19.6% (n=11) (Table 18, Figure 15).

Table 18: Laboratory and Radiological Findings

Parameter	Abnormal (%)
Elevated WBC count	39.3%
Neutrophilia	41.1%
Eosinophilia	30.4%
Raised CRP	42.9%
Raised ESR	49.1%
Abnormal CXR	19.6%

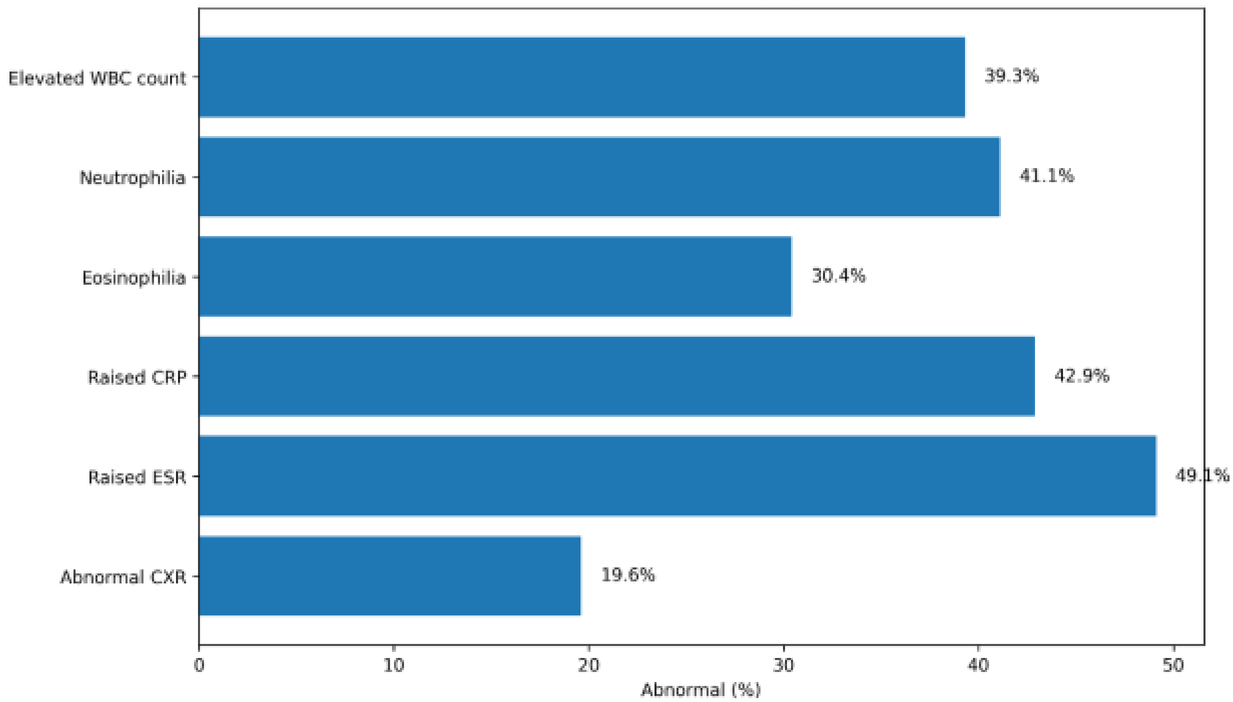

Figure 15: Distribution of Abnormal laboratory & Radiological Findings

3.10 In-hospital treatment and outcomes

Nebulization and systemic steroids were administered to most patients, with nebulization given to all 56 patients (100%) and systemic steroids to 54 patients (96.4%). Oxygen therapy was required in 32.1% (n=18), and antibiotics were used in 48.2% (n=27) (Table 19, Figure 16). Most patients were managed on the ward (n=43, 76.8%), while high-dependency unit (HDU) care was necessary in 21.4% (n=12), and intensive care unit (ICU) admission was required in 1.8% (n=1) (Table 20, Figure 17).

The mean duration of hospital admission was 5.46 days, with a median of 4 days and a range of 2–20 days. Complications were observed in 9 patients (n=9, 16.1%) during hospitalization. The most common complication was sepsis/septic shock, occurring in 8 patients (n=8, 14.3%). Myocardial infarction was documented in 1 patient (n=1, 1.8%), and type 2 respiratory failure was observed in 1 patient (n=1, 1.8%).

All patients were successfully discharged following clinical improvement.

Table 19: Acute Management During Hospitalization

Treatment	Frequency (n)	Percentage (%)
Nebulisation	56	100%
Systemic corticosteroids	54	96.4%

Treatment	Frequency (n)	Percentage (%)
Oxygen therapy	18	32.1%
Antibiotics	27	48.2%

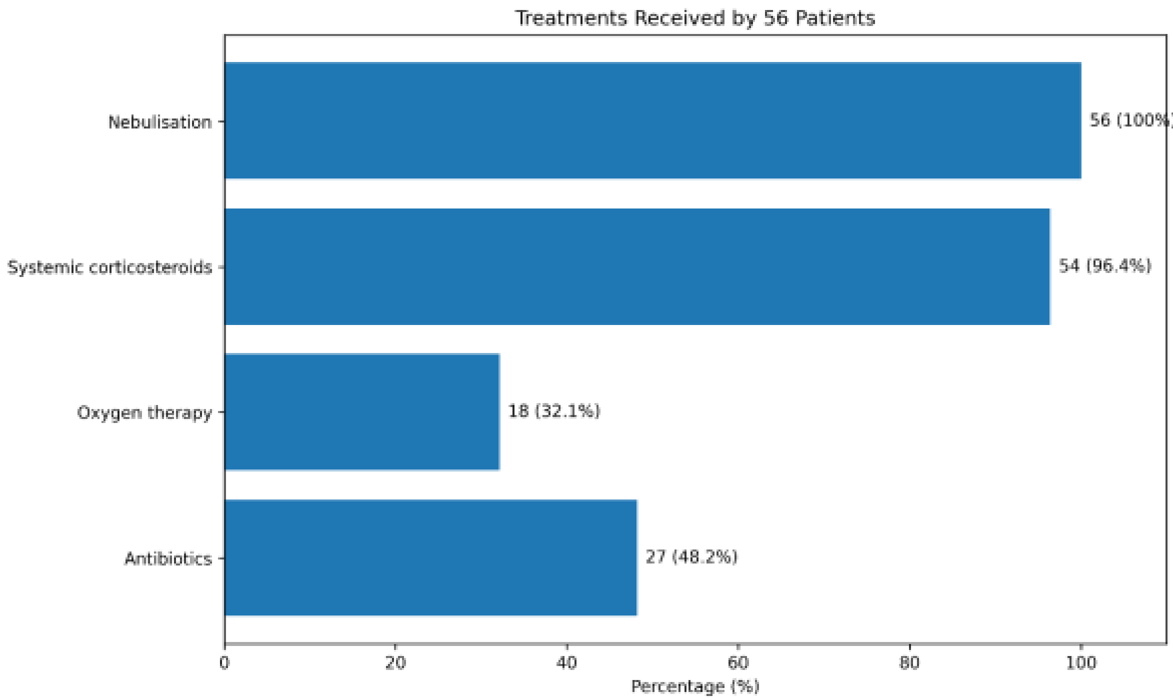

Figure 16: Distribution of Treatments

Table 20: Frequencies of Level of care

Level of Care	Frequency (n)	Percentage (%)
Ward care	43	76.8%
HDU care	12	21.4%
ICU care	1	1.8%
Total	56	100.0%

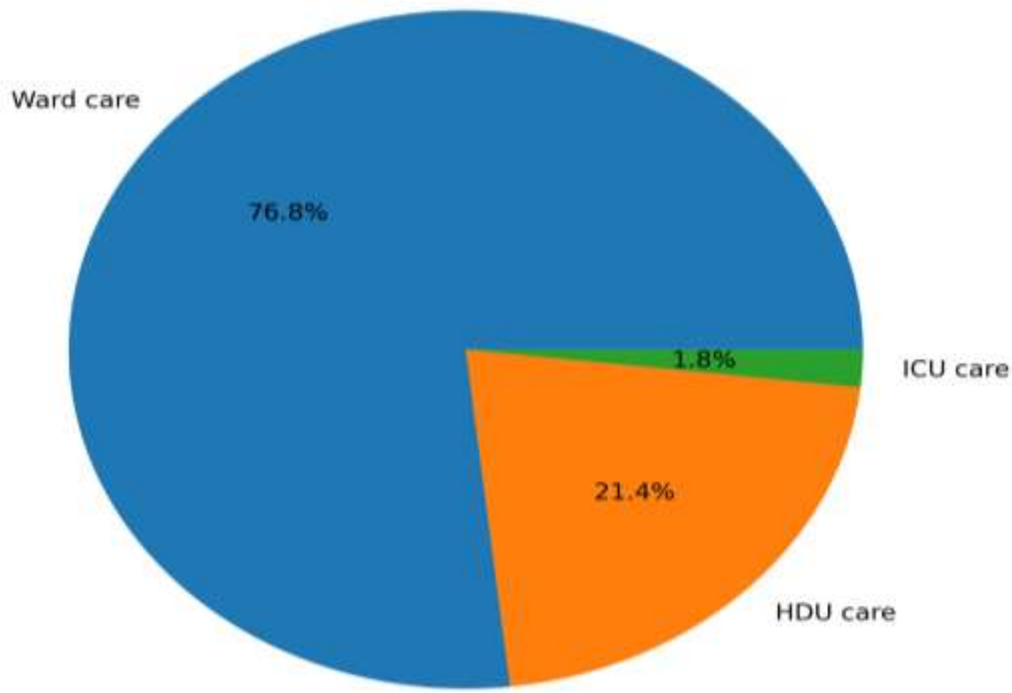

Figure 17: Distribution of Level of Care

3.11 Follow-up outcomes

Follow-up symptoms were improved in 91.1% (n=51). Follow-up ACT category showed well-controlled (20–25) status in 85.7% (n=48). Follow-up treatment compliance was mostly good (n=52, 92.9%) and inhaler technique was correct in 76.8% (n=43) (Table 22, Figure 19).

Table 21: Frequencies of Follow-Up Outcomes

Outcome	Frequency (n)	Percentage (%)
Improved at discharge	56	100.0%
Improved symptoms at follow-up	51	91.1%
Well-controlled ACT at follow-up	48	85.7%
Good treatment compliance	52	92.9%
Correct inhaler technique	43	76.8%

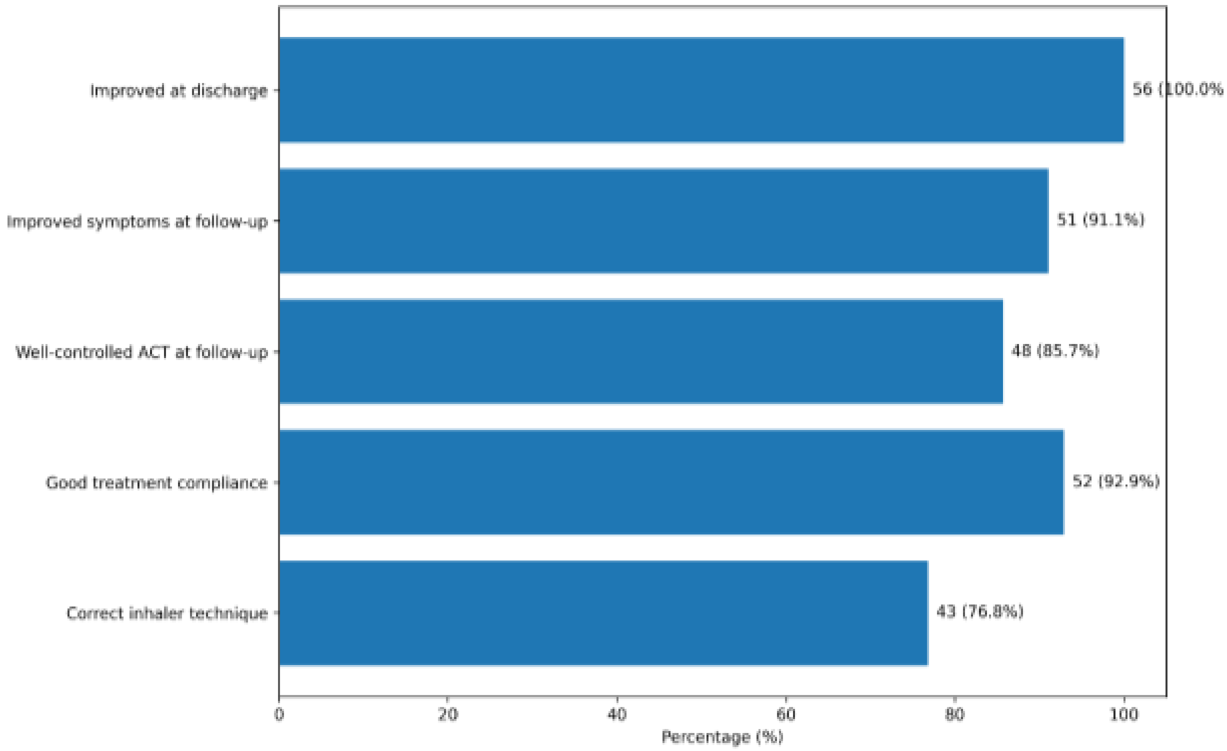

Figure 18: Distribution of Follow up Outcomes

3.12 Association analyses using severity of asthma as the outcome

Because several contingency tables contained small cell counts, Fisher's exact test was considered the primary inferential test whenever sparse distributions were expected (i.e., small subgroup sizes or multiple-category predictors).

3.12.1 Factors associated with severity of asthma

Asthma Control Test (ACT) category demonstrated a strong association with asthma severity ($p < 0.001$, Fisher's exact test), with poor asthma control more frequently observed among patients in higher severity categories. The absence of comorbidities was also significantly associated with asthma severity ($p < 0.001$, Fisher's exact test), as patients with intermittent asthma were more likely to have no comorbidities compared with those in persistent asthma groups. Functional limitation showed a statistically significant association with asthma severity ($p = 0.024$, Fisher's exact test), and the presence of fever was also associated with increased severity ($p = 0.042$, Fisher's exact test). Baseline treatment compliance was significantly associated with severity ($p = 0.029$, Fisher's exact test), while inhaler technique also demonstrated a significant association ($p = 0.019$, Fisher's exact test), with incorrect technique more frequently observed among persistent asthma categories. In addition, atopy was significantly associated with asthma severity ($p = 0.040$, Fisher's exact test) in this cohort.

3.12.2 Factors not significantly associated with severity of asthma

No statistically significant association was observed between asthma severity and gender (p=0.806 Fisher), duration of asthma (p=0.533 Fisher), major individual comorbidities (e.g., DM, HT, DL, IHD, renal disease; all p>0.05), smoking status (p=0.803 Fisher), indoor pollution exposure (p=0.884 Fisher), outdoor pollution exposure (p=0.856 Fisher), obesity (p=0.635 Fisher), or most symptom variables when analysed individually.

Duration of hospital admission did not differ significantly across asthma severity categories (Kruskal–Wallis p = 0.521) in this sample.

3.13 Compliance to treatment and response to therapy

3.13.1 Biochemical response

An association between treatment compliance and biochemical response was assessed using contingency table analysis. Among patients with good compliance, 51.3% demonstrated a biochemical response, compared to 17.6% among those with poor compliance.

Table 22: Compliance to Treatment vs. Biochemical Response

Compliance to Treatment		Biochemically Responded		Total
		No	Yes	
No	Observed (n)	14	3	17
	% within row	82.4%	17.6%	100.0%
Yes	Observed (n)	19	20	39
	% within row	48.7%	51.3%	100.0%
Total	Observed (n)	33	23	56
	% within row	58.9%	41.1%	100.0%

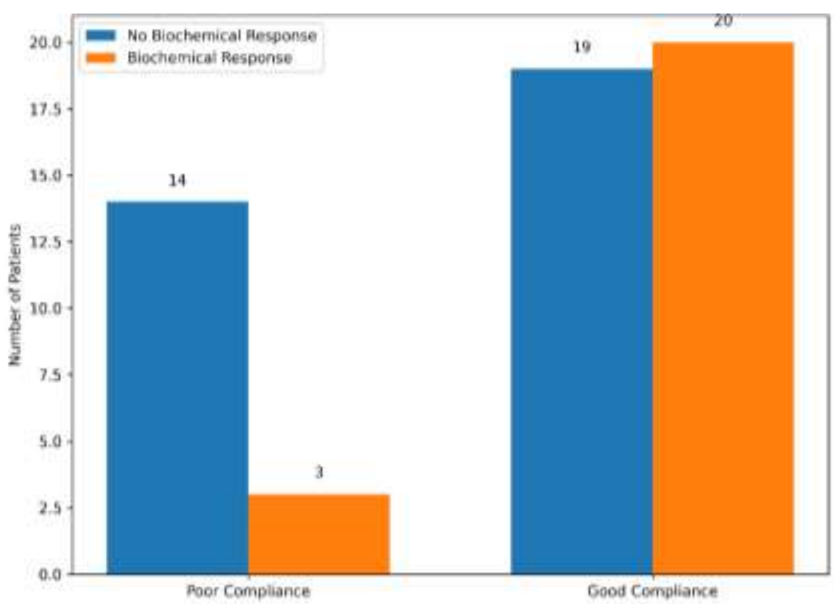

Figure 19: Treatment Compliance vs Biochemical Response

3.13.2 Compliance to treatment and level of care

The association between treatment compliance and level of care required during hospitalization (ward, HDU, ICU) was analysed using Fisher's exact test due to sparse cell counts.

There was no statistically significant association between treatment compliance and level of care (Fisher's exact $p = 0.815$)

Table 23: Compliance to Treatment vs. Level of Care

Compliance to Treatment		Level of Care			Total
		HDU	ICU	Ward	
No	Observed (n)	3	0	14	17
	% within row	17.6%	0.0%	82.4%	100.0%
Yes	Observed (n)	9	1	29	39
	% within row	23.1%	2.6%	74.4%	100.0%
Total	Observed (n)	12	1	43	56
	% within row	21.4%	1.8%	76.8%	100.0%

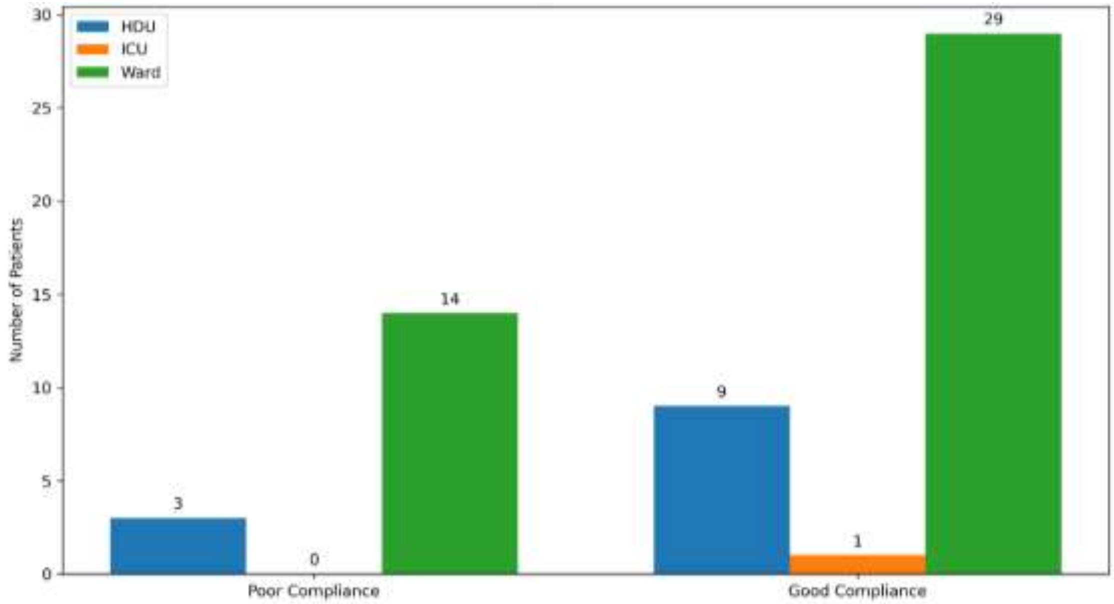

Figure 20: Treatment Compliance vs Level of Care

3.13.3 Compliance to treatment and duration of hospital admission

The duration of hospital admission was compared between patients with good and poor compliance using the Mann–Whitney U test. There was no statistically significant difference in length of stay between the two compliance groups (U = 238, p = 0.083)

3.14 Smoking status and asthma control (ACT category)

The association between smoking status (current, former, never smoker) and asthma control status (ACT category) was assessed using contingency table analysis. Due to multiple low expected cell counts, Fisher's exact test was used for interpretation.

There was no statistically significant association between smoking status and asthma control (Fisher's exact p = 0.245)

3.15 Inhaler Technique Before and After Hospital Admission

Prior to hospital admission, only 18 patients (32.1%) demonstrated correct inhaler technique, while the majority, 38 patients (67.9%), had incorrect inhaler technique.

Following in-hospital education and demonstration, a significant improvement was observed. At follow-up, 46 patients (82.1%) demonstrated correct inhaler technique, whereas only 10 patients (17.9%) continued to use incorrect technique.

This finding indicates substantial improvement in inhaler technique following structured patient education during hospitalization.

Table 24: Inhaler Technique Before and After Admission

Inhaler Technique	Before Admission n (%)	After Admission n (%)
Correct Technique	18 (32.1%)	46 (82.1%)
Incorrect Technique	38 (67.9%)	10 (17.9%)
Total	56 (100.0%)	56 (100.0%)

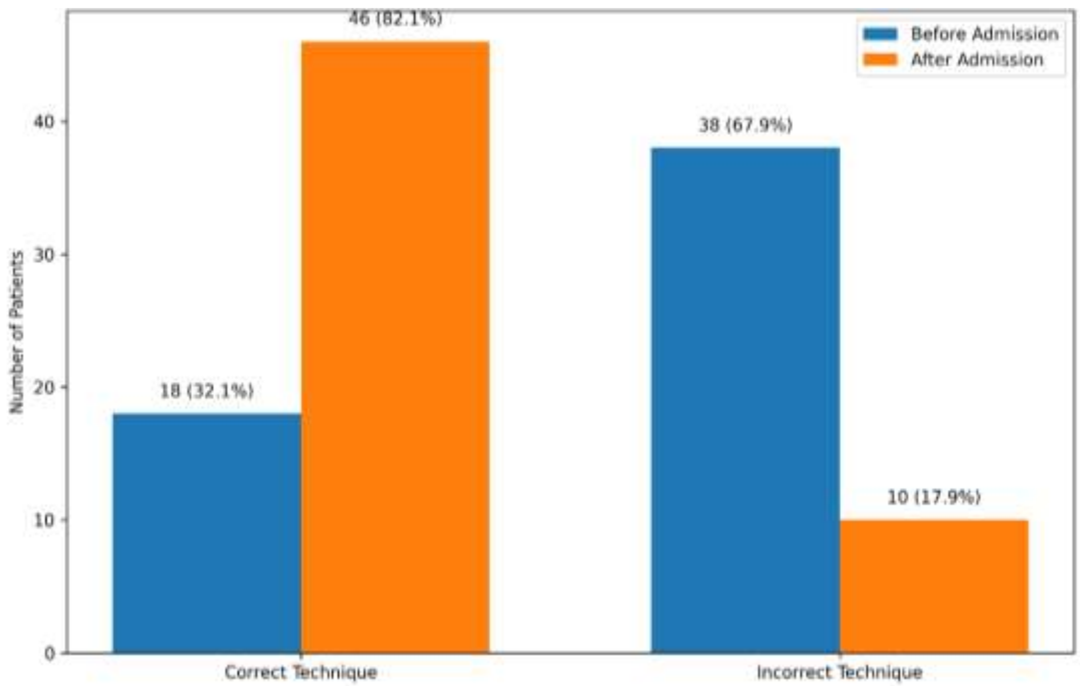

Figure 21: Improvement in Inhaler Technique Before & After Hospital Admission

3.15 ACT Score Before and After Hospital Admission

Prior to hospital admission, the majority of patients (n=32, 57.1%) were in the very poorly controlled ACT category (score 5–15). Only 6 patients (10.7%) had well-controlled asthma before admission.

Following treatment and structured education during hospitalization, a marked improvement in asthma control was observed. At follow-up, 38 patients (67.9%) achieved well-controlled status, while only 6 patients (10.7%) remained in the very poorly controlled category.

The mean ACT score improved significantly from 13.4 (±3.2) before admission to 20.8 (±2.9) after admission.

Table 25: ACT Score Categories Before and After Admission

ACT Score Category	Interpretation	Before Admission n (%)	After Admission n (%)
20–25	Well Controlled	6 (10.7%)	38 (67.9%)
16–19	Not Well Controlled	18 (32.1%)	12 (21.4%)

ACT Score Category	Interpretation	Before Admission n (%)	After Admission n (%)
5–15	Very Poorly Controlled	32 (57.1%)	6 (10.7%)
Total		56 (100.0%)	56 (100.0%)

Table 26: Mean ACT Score before and after admission

ACT Score	Mean (SD)
ACT Before Admission	13.4 (±3.2)
ACT After Admission	20.8 (±2.9)

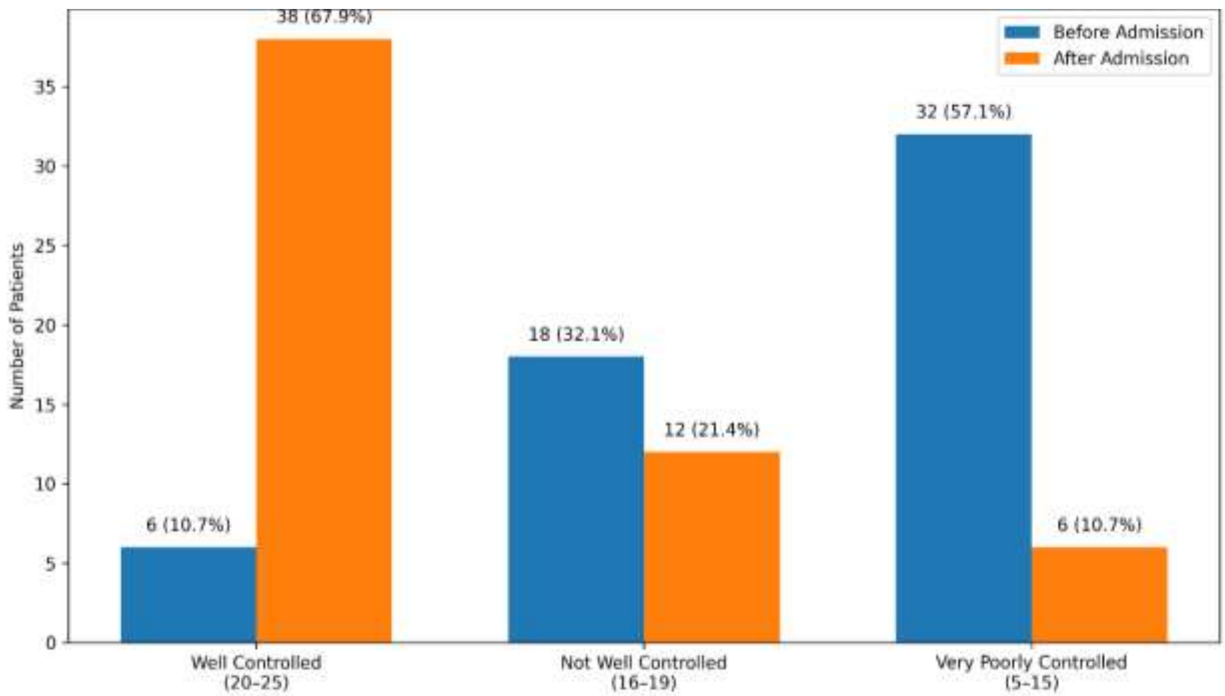

Figure 22: ACT Categories Before & After Hospital Admission

Discussion

This prospective study demonstrates that asthma exacerbations requiring hospitalization in this Sri Lankan cohort are largely driven by modifiable and interrelated factors, particularly poor baseline asthma control, suboptimal treatment adherence, incorrect inhaler technique, and substantial environmental exposures. A notable finding is that the majority of patients presented with multiple concurrent risk factors, reinforcing the concept that exacerbations in real-world settings arise from cumulative risk burden rather than a single precipitating trigger[4]. This has important implications for both clinical management and prevention strategies.

A key observation in this study is the high prevalence of poorly controlled asthma prior to admission and its strong association with exacerbation severity. This finding is consistent with previous evidence demonstrating that inadequate baseline control is one of the strongest predictors of severe exacerbations and hospitalization[3]. Persistent airway inflammation in poorly controlled asthma increases susceptibility to environmental and infectious triggers, predisposing patients to acute deterioration[4]. Real-world studies from Asian populations further support this, showing that suboptimal control is closely linked to increased exacerbation risk and healthcare utilization[11,12]. These findings emphasize that hospital admissions often represent a failure of long-term disease control rather than unpredictable acute events.

Treatment adherence emerged as a critical determinant of exacerbation severity in this study. Patients with poor compliance were more likely to experience severe exacerbations, consistent with systematic evidence demonstrating that inadequate adherence to inhaled corticosteroids significantly increases exacerbation risk[5]. Large cohort studies have shown that patients with incomplete medication adherence have substantially higher rates of exacerbations, emergency visits, and systemic corticosteroid use[11,12]. From a mechanistic perspective, inconsistent use of inhaled corticosteroids results in ongoing airway inflammation and heightened airway responsiveness, thereby lowering the threshold for exacerbations[4]. In this context, adherence should be viewed not merely as a behavioral issue but as a central component of disease pathophysiology.

Incorrect inhaler technique was also highly prevalent prior to admission and was significantly associated with disease severity. Importantly, inhaler technique improved markedly following structured education during hospitalization, indicating that this is a readily modifiable factor. Previous studies have demonstrated that educational interventions significantly improve inhaler technique and clinical outcomes[6]. Local data from Sri Lanka further highlight gaps in asthma management practices, including suboptimal inhaler use and inadequate patient education[13]. These findings suggest that deficiencies in both patient knowledge and healthcare delivery contribute to poor asthma control, underscoring the importance of regular assessment and reinforcement of inhaler technique in routine practice.

Environmental exposures were highly prevalent in this cohort, particularly indoor air pollution and biomass fuel use, reflecting the local context. Air pollution has been widely implicated in asthma exacerbations through mechanisms such as oxidative stress, airway inflammation, and impaired mucosal defense[3]. Globally, household air pollution remains a major public health issue, with billions of individuals exposed to harmful indoor pollutants, particularly in low- and middle-income countries[9]. The American Thoracic Society has emphasized the substantial respiratory health burden associated with such exposures, especially in resource-limited settings[2]. Although statistical associations with severity were not consistently observed in this study, the high prevalence of exposure suggests that environmental factors contribute significantly to the baseline vulnerability of this population. Regional epidemiological data further indicate that contextual and environmental factors play an important role in shaping asthma burden across different populations[1].

Respiratory infections were identified as an important precipitating factor, consistent with established evidence that viral and bacterial infections are major triggers of asthma exacerbations[4]. Infections can amplify airway inflammation and precipitate acute clinical deterioration, particularly in patients with poor baseline control. The relatively frequent use of antibiotics observed in this study reflects real-world clinical practice and parallels findings from Sri Lanka, where variability and potential overuse of antibiotics in asthma exacerbations have been reported[14]. This highlights the need for improved diagnostic strategies and rational antimicrobial use in managing exacerbations.

An important contribution of this study is the demonstration of a high burden of multiple concurrent risk factors among hospitalized patients. The majority of patients exhibited three or more contributing determinants, supporting the concept of an “exacerbation-prone” phenotype[2]. This finding is particularly relevant in low-resource settings, where environmental exposures, healthcare access limitations, and behavioral factors coexist. It suggests that focusing on individual risk factors in isolation may be insufficient and that a comprehensive, multifactorial approach to asthma management is required.

Comorbidities were frequently observed in this cohort; however, no significant association with exacerbation severity was identified. While previous studies have shown that comorbid conditions can influence asthma outcomes and complicate management[10], their impact in this study may have been overshadowed by more dominant modifiable factors such as adherence and environmental exposure. Alternatively, the lack of association may reflect limitations related to sample size. Clinical outcomes in this study were favorable, with low rates of intensive care admission and no mortality. This likely reflects the effectiveness of timely, guideline-based management, including oxygen therapy, bronchodilators, and systemic corticosteroids, as recommended in current clinical guidelines[6,15]. Oxygen supplementation was administered not only to patients with documented hypoxaemia (SpO_2 <94%) but also to those with significant respiratory distress, tachypnoea, and increased work of breathing, consistent with standard acute asthma management practices. However, the high prevalence of preventable risk factors identified suggests that many of these hospitalizations could potentially be avoided through improved outpatient care and early intervention.

From a clinical and public health perspective, these findings have several important implications. First, improving long-term asthma control through adherence to maintenance therapy remains fundamental, in line with international guideline recommendations[7,8]. Second, structured patient education—particularly regarding inhaler technique—should be integrated into routine care. Third, addressing environmental exposures, especially indoor air pollution, is essential in reducing disease burden in low- and middle-income settings[9]. Finally, adopting a multifactorial approach to risk assessment may help identify high-risk patients and guide targeted interventions aimed at preventing exacerbations and reducing healthcare utilization.

Conclusion

Asthma exacerbations requiring hospitalization in this setting are predominantly driven by modifiable and interrelated factors, particularly poor baseline asthma control, suboptimal treatment adherence, incorrect inhaler technique, and significant environmental exposures. The high prevalence of multiple concurrent risk factors highlights the multifactorial nature of exacerbations and underscores the need for comprehensive patient assessment. These findings suggest that a substantial proportion of asthma-related hospitalizations may be preventable through improved long-term disease control, patient education, and optimization of inhaler technique. Addressing environmental exposures, particularly indoor air pollution, is also critical in reducing disease burden in resource-limited settings. A multifaceted approach integrating adherence-focused interventions, structured education, and environmental risk reduction is essential to improve outcomes and reduce preventable exacerbations in patients with asthma.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, it was conducted in a single tertiary care center, which may limit the generalizability of the results to other settings, particularly primary care or community-based populations. Second, the sample size was relatively small, which may have reduced the statistical power to detect associations between certain variables, particularly comorbidities and environmental exposures. Third, some data, including treatment adherence and environmental exposure, were based on patient self-report, which may be subject to recall bias and reporting inaccuracies. Although a prospective design was used to minimize such bias, it cannot be completely excluded. Fourth, the study population consisted of hospitalized patients with acute exacerbations, which may overrepresent individuals with more severe disease and limit applicability to patients with milder asthma.

Finally, the duration of follow-up was limited, and long-term outcomes such as recurrent exacerbations and sustained improvements in asthma control could not be fully assessed. Despite these limitations, the prospective design and comprehensive evaluation of multiple risk factors provide valuable insights into the determinants of asthma exacerbations in this setting. Furthermore, the cohort was predominantly composed of female, non-smoking patients, many of whom were housewives, resulting in relatively limited direct tobacco smoke exposure. This demographic characteristic may partly explain the absence of a statistically significant association between smoking status and exacerbation severity in the present study.

Recommendations

Based on the findings of this study, several recommendations can be made to improve asthma management and reduce preventable exacerbations. First, strengthening long-term asthma control should be a primary focus, with emphasis on improving adherence to maintenance therapy, particularly inhaled corticosteroids. Regular follow-up and monitoring of asthma control using validated tools such as the Asthma Control Test should be incorporated into routine clinical practice.

Second, structured patient education programs should be implemented to address gaps in inhaler technique and disease understanding. Assessment and reinforcement of correct inhaler technique should be performed at every clinical encounter, as this represents a readily modifiable factor with significant impact on disease control.

Third, targeted interventions to improve treatment adherence should be developed, including patient counseling, simplified treatment regimens where possible, and improved communication between healthcare providers and patients. Addressing behavioral and health system barriers to adherence is essential for achieving sustained disease control.

Fourth, environmental risk factors, particularly indoor air pollution and biomass fuel exposure, should be addressed through public health interventions and patient-level counseling. Increasing awareness of the impact of environmental exposures and promoting cleaner household energy practices may help reduce asthma morbidity in resource-limited settings.

Fifth, rational use of antibiotics should be encouraged in the management of asthma exacerbations, with efforts to improve diagnostic accuracy and promote antimicrobial stewardship in clinical practice.

Finally, further research is recommended to evaluate long-term outcomes, recurrent exacerbations, and the effectiveness of targeted interventions in improving asthma control. Larger multicenter studies are needed to enhance generalizability and provide more robust evidence applicable to diverse populations.

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