

Spectrum of Pediatric Asthma: Demographic, Allergic Comorbidities
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Clinic at Sabratha Teaching Hospital, Sabratha, Libya

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Abstract:

Asthma is a heterogeneous chronic respiratory disease and a substantial cause of morbidity in children worldwide. Coexisting allergic comorbidities and environmental exposures are known to influence disease control, but data characterizing these relationships in Libyan pediatric populations remain limited. This study aimed to evaluate the prevalence of asthma control status among children attending a respiratory clinic in northwestern Libya, to characterize the spectrum of allergic comorbidities and environmental exposures and triggers in this population, and to identify factors independently associated with asthma control status. This cross-sectional study included 150 children with asthma attending the respiratory clinic at

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Sabratha Teaching Hospital. Asthma control was classified as Controlled, Suboptimally Controlled, or Uncontrolled using a composite index adapted from Global Initiative for Asthma (GINA) principles. Demographic, allergic, and environmental data were collected, and spirometry, where feasible, was expressed as % predicted and z-scores using GLI-2012 reference equations. Associations with control status were assessed using chi-square/Fisher's exact and Kruskal-Wallis tests, followed by multivariable ordinal and binary logistic regression. Uncontrolled asthma was present in 60.7% (n=91) of children. Allergic rhinitis (84.0%), family history of asthma (84.7%), and allergic conjunctivitis (46.0%) were highly prevalent; cold (71.3%) and dust (68.7%) were the most frequently reported triggers, and winter was the predominant peak season (46.7%). On multivariable analysis, incorrect inhaler technique (adjusted OR 3.45, 95% CI 1.50–7.97, $p=0.004$) and tobacco smoke as a trigger (adjusted OR 2.33, 95% CI 1.15–4.70, $p=0.019$) were independently associated with poor control. Among the 32.7% of children who completed spirometry, lung function indices did not differ significantly across control groups (all $p>0.12$). Asthma control remains poor among this cohort of Libyan children. Since inhaler technique errors and smoke-trigger sensitivity are independently associated with poor asthma control, targeted inhaler-technique education seems needed as a practical, modifiable intervention to improve pediatric asthma outcomes in this setting.

Keywords: Asthma, Allergic Comorbidities, Environmental Triggers, Family History, Inhaler Technique, Control Status.

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طيف ربو الأطفال: الديموغرافيا، الأمراض التحسسية المصاحبة، والمثيرات البيئية بين الأطفال المترددين على عيادة الجهاز التنفسي بمستشفى صبراتة التعليمي، صبراتة، ليبيا

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الملخص

الربو مرض تنفسي مزمن غير متجانس، ويُعد سبباً رئيساً للاعتلال لدى الأطفال في مختلف أنحاء العالم. ومن المعروف أن الأمراض التحسسية المصاحبة والتعرضات البيئية تؤثر في مدى السيطرة على المرض، غير أن البيانات التي تصف هذه العلاقات لدى الأطفال في ليبيا لا تزال محدودة. هدفت هذه الدراسة إلى تقييم معدل انتشار حالات السيطرة على الربو بين الأطفال المترددين على عيادة الأمراض التنفسية في شمال غرب ليبيا، وإلى وصف طيف الأمراض التحسسية المصاحبة والتعرضات البيئية والمحفزات في هذه الفئة، وتحديد العوامل المرتبطة ارتباطاً مستقلاً بحالة السيطرة على الربو. شملت هذه الدراسة المقطعية 150 طفلاً مصاباً بالربو من مرثادي عيادة الأمراض التنفسية بمستشفى صبراتة التعليمي. صُنفت السيطرة على الربو إلى: مسيطر عليه، ومسيطر عليه بصورة دون المثلى، وغير مسيطر عليه، باستخدام مؤشر مركب مقتبس من مبادئ المبادرة العالمية للربو (GINA). جُمعت البيانات الديموغرافية والتحسسية والبيئية، وعُبر عن نتائج قياس التنفس (السبيرومترية)، حيثما أمكن إجراؤه، كنسبة مئوية من القيمة المتوقعة وكدرجات معيارية (z-scores) باستخدام معادلات المرجع GII-2012. وجرى تقييم

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الارتباط بحالة السيطرة باستخدام اختبار مربع كاي أو اختبار فيشر الدقيق واختبار كروسكال - واليس، تلاه تحليل الانحدار اللوجستي الترتيبي والثنائي متعدد المتغيرات. كان الربو غير مسيطر عليه لدى 60.7% (العدد = 91) من الأطفال. وسُجّلت نسب انتشار مرتفعة للالتهاب الأنفي التحسسي (84.0%)، والتاريخ العائلي للربو (84.7%)، والتهاب الملتحمة التحسسي (46.0%)؛ وكان البرد (71.3%) والغبار (68.7%) أكثر المحفزات المبلغ عنها، فيما مثل فصل الشتاء الموسم الذروي الغالب (46.7%). وفي التحليل متعدد المتغيرات، ارتبط كلٌّ من الاستخدام الخاطئ لجهاز الاستنشاق (نسبة الأرجحية المعدلة 3.45؛ فاصل الثقة 95%: 1.50-7.97؛ القيمة الاحتمالية = 0.004) ودخان التبغ كمحفّز (نسبة الأرجحية المعدلة 2.33؛ فاصل الثقة 95%: 1.15-4.70؛ القيمة الاحتمالية = 0.019) ارتباطاً مستقلاً بضعف السيطرة. ومن بين 32.7% من الأطفال الذين أتموا قياس التنفس، لم تختلف مؤشرات وظائف الرئة اختلافاً ذا دلالة إحصائية بين مجموعات السيطرة (جميع القيم الاحتمالية < 0.12). لا تزال السيطرة على الربو ضعيفة لدى هذه المجموعة من الأطفال الليبيين. ولما كانت أخطاء تقنية استخدام جهاز الاستنشاق والحساسية لدخان التبغ مرتبطتين ارتباطاً مستقلاً بضعف السيطرة على الربو، فإن التنقيف الموجّه حول تقنية استخدام جهاز الاستنشاق يبدو ضرورياً بوصفه تدخلاً عملياً قابلاً للتعديل لتحسين نتائج الربو لدى الأطفال في هذا السياق.

الكلمات المفتاحية: الربو لدى الأطفال، السيطرة على الربو، الأمراض التحسسية المصاحبة، تقنية جهاز الاستنشاق، ليبيا

1. Introduction:

Asthma is a heterogeneous chronic respiratory disease characterized by variable respiratory symptom, most commonly wheeze, shortness of breath, chest tightness, and cough, in association with variable expiratory airflow limitation (Conrad et al., 2021). As the symptoms fluctuate in intensity and frequency, the diagnosis of asthma is based on a characteristic clinical history supported, whenever feasible, by objective evidence of variable airflow obstruction or bronchial hyperresponsiveness (Venkatesan, 2025).

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In children, diagnostic assessment requires particular care because recurrent wheeze may accompany viral infections and other conditions that can mimic asthma.

Pediatric asthma remains a substantial global health problem. Acute exacerbations place a considerable burden on children, families, and health services through emergency-department visits, hospital admissions, school absence, and, in the most severe cases, death (Hsiao et al., 2024; Moore et al., 2023; Rosser et al., 2022). Exacerbations are multifactorial and reflect interactions among airway inflammation, genetic and atopic susceptibility, viral infections, medication use, and environmental exposures (Sousa et al., 2025). Ambient particulate matter, black carbon, temperature extremes, and wildfire smoke have each been associated with short-term increases in respiratory morbidity in susceptible children (Hwang et al., 2023; Moore et al., 2023; Schinasi et al., 2022; Uppala et al., 2025). Children may be especially vulnerable to environmental triggers because their airways and immune systems are still developing, they breathe a greater volume of air relative to body size, and they may spend substantial time outdoors (Brumberg and Karr, 2021; Miteva et al., 2023). Nevertheless, the contribution of any individual exposure varies by location, season, baseline disease severity, allergen sensitization, and access to preventive treatment. Accordingly, regional evidence should be interpreted as relative rather than directly transferable to the Libyan population. The relationship between allergic rhinitis and asthma is commonly described within the framework of united airway disease. The upper and lower airways share anatomical, epithelial, immunological, and inflammatory features; as a result, inflammation in the nose and paranasal sinuses may influence lower-airway symptoms and asthma control (Giavina-Bianchi et al., 2016). Allergic rhinitis may precede asthma in some children as part of the atopic march, although this sequence is not universal and should not be interpreted as an inevitable causal progression (Bantz et al., 2014). Recognizing these coexisting conditions is clinically important because children with asthma and allergic rhinitis may experience poorer disease control and a greater risk of acute-care utilization than children with asthma alone (Bantz et al., 2014; Serebrisky and Wiznia, 2019).

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Medication adherence is another potentially modifiable determinant of asthma control, but its relationship with exacerbations is not straightforward. In a nested case-control study of Dutch children, higher refill adherence to inhaled corticosteroids was paradoxically associated with more exacerbations among those using a long-acting β_2 -agonist; the authors interpreted this finding as potentially reflecting confounding by disease severity and treatment behavior rather than a harmful effect of adherence itself (Vasbinder et al., 2016). Conversely, a systematic review of pediatric randomized trials found that electronic monitoring devices improved inhaler adherence but did not produce statistically significant improvements in exacerbations, lung function, or asthma control (Lee et al., 2021). Taken together, these findings suggest that improving adherence is necessary but may not be sufficient to prevent exacerbations when treatment intensity, inhaler technique, comorbid allergic disease, environmental exposure, and baseline severity are not simultaneously addressed (Engelkes et al., 2015; Lee et al., 2021; Vasbinder et al., 2016).

This study aimed to describe the demographic and clinical characteristics of a cohort of children with asthma attending a respiratory clinic in Northwestern Libya, to determine the distribution of asthma control status within this population, to characterize the spectrum of allergic comorbidities and environmental exposures and triggers, and to examine their association with asthma control status.

2. Materials and Methods

2.1 Study Design and Settings

This was a hospital based cross-sectional analytical study. The study was carried out at the pediatric respiratory clinic of (STH), Sabratha, Libya, over a 5-month period (November 2024 to March 2025). All children aged 3-17 years with diagnosed bronchial asthma attending the clinic during study duration were consecutively recruited. Informed verbal consent and assent were obtained from the caregivers and older children, respectively. Children less than 3 years of age or with incomplete records or refusal of the parent or

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guardian to participate were excluded from the study. Data were collected using structured data collection sheet administered by the respiratory specialist attending the clinic during clinic visits. Data collected included demographic characteristics, clinical history, allergic comorbidities, environmental triggers, and anthropometrics and spirometry measurements. Data were exported to Microsoft Excel for cleaning and preparation prior to statistical analysis. For the variable (Duration of acute attack), it was converted into three tiers (Short, Moderate, Prolonged) based on clinical duration as follows, Short: less than 1 week, Moderate: from 1 week to 10 days, and Prolonged: more than 10 days. For the (Adherence to controller therapy), it was grouped into three target categories according to caregiver-report (Good: regular use, Partial: irregular use, and Poor: stopped, completely non-adherent, or answered "No"). To assess inhaler technique, the respiratory specialist asked the child or caregiver to demonstrate the procedure. The specialist recorded the evaluation results directly onto the structured data collection sheet during the administration.

2.2 Spirometry Data Analysis

Not all children were able to perform spirometry reliably, primarily due to young age; spirometry was successfully completed in 49 of 150 children (32.7%). For this subgroup, raw forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC) were converted to percentage of predicted value (% predicted) and z-scores using the Global Lung Function Initiative (GLI-2012) calculator (Quanjer et al., 2012), which adjust for the child's age, height, sex, and ethnicity. Raw (absolute) FEV1 and FVC values in liters were retained in the dataset but were not used for between-group comparisons, as these are confounded by the child's age and height; only the (age/height/sex-adjusted) (% predicted and z-score) values were used for inferential analysis.

2.3 Classification of Asthma Control

According to the standard Global Initiative for Asthma (GINA) control assessment we can classify asthma control into three tiers or groups as follow controlled, partly-controlled, and uncontrolled based on four-items over the previous four weeks: daytime symptoms more than twice a week, any night waking due to asthma,

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reliever use more than twice a week and any activity limitation due to asthma (Global Initiative for Asthma, 2025). As our dataset did not capture the full criteria used in the standard Global Initiative for Asthma (GINA) control assessment, we classified asthma control using a composite score reconstructed from the GINA framework based on three collected clinical variables: number or frequency of asthma attacks in the last six months, duration of the acute attack, and the caregiver-reported level of adherence to controller therapy (Baldacci et al., 2019). Each component was scored 0, 1, or 2 (with lower scores indicating better control) and summed to give a total score ranging from 0 to 6. Accordingly, children were then classified as Controlled (score 0-1), Suboptimally Controlled (score 2-3), or Uncontrolled (score 4-6). Because these three components were used to build the control status classification, they were not subsequently tested as independent predictors of control status, as doing so would be circular.

2.4 Statistical Analysis

All analysis were performed in jamovi (Version 2.7) (The jamovi project, 2025), using the jmv module and the GAMLj3 module for ordinal and binary logistic regression (Gallucci, M., 2019). Categorical variables as sex, residency, history of breast feeding, allergic comorbidities, family history, environmental triggers, and asthma control were reported as frequencies and percentages. Continuous variables like age height, weight, BMI, and all spirometry indices were summarized using means and standard deviations for normally distributed variables and median was added for nonnormally distributed ones. Normality was assessed using the Shapiro-Wilk test. Height was normally distributed; age, weight, BMI, and all spirometry indices deviated significantly from normality ($p < 0.001$ to $p = 0.019$). Differences in continuous variables (anthropometric and spirometry indices) across the three control groups were assessed using the Kruskal-Wallis test, given the non-normal distribution of these variables, while categorical variables were analyzed using Pearson's Chi-square test and Fisher's exact test as appropriate. Following the predictor screening and outcome-collapsing strategy, a three-tier ordinal (proportional-

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odds, cumulative-link) logistic regression was fitted with asthma control status as the ordinal outcome, and a corresponding binary logistic regression was fitted with Control_Binary as the outcome. Effect estimates from both models are reported as odds ratios (OR) with 95% confidence intervals (CI). The level of significance at 95% confidence interval (CI) was taken at $p < 0.05$.

2.5 Predictor Screening

A two-stage variable selection strategy was adopted, rather than entering all variables into a single multivariable model, due to the number of candidate demographic, allergic, and environmental variables collected relative to the number of children in the smallest control category. In the first stage, each candidate variable was screened individually against the three tier asthma control status using the univariate tests detailed below. Variables meeting a threshold of $p < 0.20$ were considered candidates for multivariable modelling, a common approach in applied research (Ullmann et al., 2024), and the final model was not based on p-values alone. Variables used to derive the control classification itself (attack frequency, attack duration, and adherence) were excluded from this screening step, as testing them would be circular. Because the three-tier control classification left only 14 children (9.3%) in the Controlled category, the events-per-variable exploratory limited how many predictors could be reliably estimated in the ordinal (three-tier) model. To provide a second, more sample-size-robust assessment of these associations, the three-tier classification was further collapsed into a binary outcome, Control_Binary, by pooling the Controlled and Suboptimally Controlled categories (Controlled/Suboptimally Controlled, $n=59$) and contrasting them with the Uncontrolled category ($n=91$) (Kiljander et al., 2020). This approach was preferred to analyzing the Controlled category alone ($n=14$ vs. 136) because it produced a more balanced distribution between outcome categories and because it captures a clinically meaningful distinction: children who are at least partially controlled versus those who are not controlled, for whom treatment step-up would be expected. The same predictors retained in the final ordinal model were then re-evaluated using this binary outcome as a secondary analysis.

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3. Results

3.1 Demographic and Clinical Characteristics of the children with asthma

A total of 150 (table 1) children were included in the analysis. The mean age was 9.75 ± 3.75 years (median 10, range 3-17), and 87 (58.0%) were male. All participants were of Libyan nationality. The most common residential area was Sabratha (50.0%), followed by Ajeilat (20.7%) and Al-Jamil (11.3%); five areas (Rigdaleen, Surman, Teeji, Zawia, and an "other/unclassified" category) together accounted for the remainder. History of breastfeeding was reported in 99 children (66.0%).

Table 1. Demographic and anthropometric characteristics of study participants (N = 150)

Variable	Value
Age (years), mean $\pm$ SD (median)	9.75 ± 3.75 (10.0)
Sex, n (%) Male	87 (58.0%)
Sex, n (%) Female	63 (42.0%)
Nationality, Libyan, n (%)	150 (100.0%)
Weight (kg), mean $\pm$ SD (median)	35.8 ± 14.6 (32.0)
Height (cm), mean $\pm$ SD	135 ± 20.5
BMI (kg/m^2), mean $\pm$ SD (median)	18.9 ± 4.71 (17.5)
History of Breastfeeding, n (%)	99 (66.0%)
Residence: Sabratha, n (%)	75 (50.0%)
Residence: Ajeilat, n (%)	31 (20.7%)
Residence: Al-Jamil, n (%)	17 (11.3%)
Residence: Surman, n (%)	16 (10.7%)
Residence: Rigdaleen, n (%)	5 (3.3%)
Residence: Other/Teeji/Zawia, n (%)	6 (4.0%)

SD, standard deviation; BMI, body mass index.

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3.2 Asthma Control Status

Using the composite control score, 14 children (9.3%) were classified as Controlled, 45 (30.0%) as Suboptimally Controlled, and 91 (60.7%) as Uncontrolled (Figure 1).

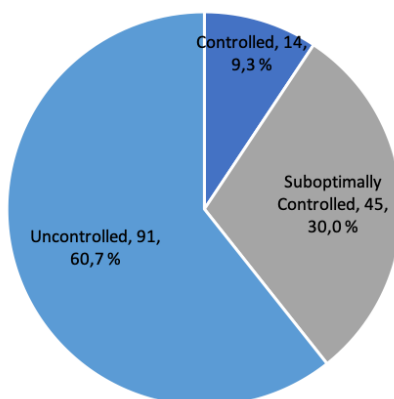


Figure 1: Distribution of Asthma Control Status (N =150)

3.3 Allergic Comorbidities and Family History

Allergic rhinitis was the most prevalent allergic comorbidity, reported in 126 children (84.0%), followed by allergic conjunctivitis (46.0%), eczema (22.7%), and food allergy (11.3%). A family history of asthma was present in 127 children (84.7%); family history of allergic rhinitis/conjunctivitis and of eczema were reported in 70.9% and 36.7%, respectively. Among those with a positive family history of asthma, the affected relative was most often "other/multiple" family members (30.0% of the total sample) or unspecified (37.3% reported no clear degree) (table 2).

Table 2. Prevalence of allergic comorbidities and family history of atopy/asthma (N = 150)

Variable	n (%)
Symptoms: food allergy	17 (11.3%)
Symptoms: eczema	34 (22.7%)
Symptoms: allergic rhinitis	126 (84.0%)

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Variable	n (%)
Symptoms: allergic conjunctivitis	69 (46.0%)
Family history: eczema	55 (36.7%)
Family history: allergic rhinitis/conjunctivitis	105/148 (70.9%)
Family history: asthma	127 (84.7%)
Degree - first-degree (parent/sibling)	26 (17.3%)
Degree - second-degree (grandparent)	23 (15.3%)
Degree - other/multiple	45 (30.0%)
Degree - none	56 (37.3%)

3.4 Environmental Exposures, Seasonal variability, peak season, and Triggers

Passive tobacco smoke exposure was reported in 77 children (51.3%), animal dander exposure in 80 (53.3%), and indoor mold/humidity in 49 of 145 respondents (33.8%). Seasonal variability in symptoms was reported by 112 of 149 respondents (75.2%). As season and trigger were multiple-response items, prevalence is reported for each individually in Table 3; winter (46.7%) was the most frequently reported peak season, and cold (71.3%) and dust (68.7%) were the most frequently reported triggers.

Table 3. Peak season of exacerbation and identified environmental triggers, individually reported (multiple responses permitted, N = 150)

Item	n (%)
Peak season - Winter	70 (46.7%)
Peak season - Autumn	41 (27.3%)
Peak season - Spring	41 (27.3%)
Peak season - Summer	22 (14.7%)
Trigger - Cold	107 (71.3%)
Trigger - Dust	103 (68.7%)

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Item	n (%)
Trigger - Perfume/strong odors	80 (53.3%)
Trigger - Tobacco smoke	79 (52.7%)
Trigger - Exercise	42 (28.0%)
Trigger - Unknown	3 (2.0%)

3.5 Factors Associated with Asthma Control Status

Family history of asthma ($p = 0.021$), inhaler technique ($p = 0.011$), and reported trigger of tobacco smoke ($p = 0.025$) were significantly associated with asthma control status on bivariate analysis; trigger of perfume/strong odors approached significance ($\chi^2 p = 0.043$, Fisher's $p = 0.052$), as did dust exposure as a trigger ($p = 0.096$) and degree of family history of asthma ($p = 0.183$). No significant association was found between control status and sex, breastfeeding history, individual allergic symptoms, family history of eczema or allergic rhinitis/conjunctivitis, passive smoking exposure, seasonal variability, peak season, animal dander exposure, indoor mold/humidity, or the remaining trigger categories (all $p > 0.20$) (Table 4).

Table 4. Association between clinical, allergic, and environmental variables and asthma control status (χ^2 / Fisher's exact test)

Variable	χ^2 (df)	p (χ^2)	p (Fisher's)
Breastfeeding history	2.68 (2)	.262	.295
Symptoms: food allergy	0.44 (2)	.802	.730
Symptoms: eczema	1.93 (2)	.381	.370
Symptoms: allergic rhinitis	1.28 (2)	.528	.486
Symptoms: allergic conjunctivitis	0.84 (2)	.656	.682
Family history: eczema	1.55 (2)	.461	.522
Family history: allergic rhinitis/conjunctivitis	2.76 (2)	.251	.249
Family history: asthma	7.73 (2)	*.021	*.025

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Variable	χ^2 (df)	p (χ^2)	P (Fisher's)
Family history of asthma, degree	8.84 (6)	.183	.182
Passive smoking exposure	1.51 (2)	.470	—
Seasonal variability (yes/no)	0.12 (2)	.944	1.000
Animal dander exposure	0.78 (2)	.678	.684
Indoor mold/humidity	1.34 (2)	.512	.549
Inhaler technique	13.0 (4)	*.011	*.012
Peak season - Autumn	0.02 (2)	.989	1.000
Peak season - Summer	0.99 (2)	.609	.688
Peak season - Spring	0.27 (2)	.874	.852
Peak season - Winter	0.71 (2)	.700	.752
Trigger - Cold	0.20 (2)	.907	.925
Trigger - Dust	4.69 (2)	.096	.090
Trigger - Perfume/strong odors	6.29 (2)	*.043	.052
Trigger - Tobacco smoke	7.42 (2)	*.025	*.023
Trigger - Exercise	0.93 (2)	.629	.700
Trigger - Unknown	0.32 (2)	.854	1.000

*Statistically significant at $p < 0.05$.

3.6 Anthropometric and Spirometry Indices by Control Status

Among the 49 children (32.7%) who successfully completed spirometry, none of the age/height/sex-adjusted lung function indices (FEV1 % predicted, FVC % predicted, FEV1/FVC % predicted, or the corresponding z-scores) differed significantly across the three control groups (all $p > 0.12$, Kruskal-Wallis) (Table 5). BMI also did not differ significantly across groups ($p = 0.173$). Raw (unadjusted) FVC in litres differed significantly across groups ($p = 0.019$); however, post-hoc comparison localized this to the Suboptimally Controlled vs. Uncontrolled groups (DSCF $p = 0.029$), and given that this raw measure is confounded by age and height rather than reflecting true group differences in lung function,

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it is not interpreted as an independent result once age/height-
adjusted values are considered.

**Table 5. Comparison of anthropometric and spirometry indices
across asthma control groups (Kruskal-Wallis test)**

Variable	χ^2 (df=2)	p	ϵ^2
BMI	3.51	.173	0.024
FEV1 % predicted	1.07	.586	0.022
FVC % predicted	3.10	.213	0.065
FEV1/FVC % predicted	4.17	.124	0.087
FEV1 z-score	1.13	.569	0.024
FVC z-score	3.17	.204	0.066
FEV1/FVC z-score	4.03	.133	0.084
FEV1, raw value (L)	3.96	.138	0.083
FVC, raw value (L)	7.94	*.019	0.165
FEV1/FVC, raw ratio	3.43	.180	0.072

**Statistically significant at $p < 0.05$; localized on post-hoc testing to the Suboptimally Controlled vs. Uncontrolled comparison (DSCF $p = .029$) and attributable to the unadjusted (non-age/height-standardized) nature of this measure. $n = 49$ for all spirometry indices.*

3.7 Multivariable Analysis of Predictors of Poor Asthma Control

Family history of asthma, inhaler technique, passive tobacco smoke exposure, and tobacco smoke as a reported trigger, which are the variables meeting the $p < 0.20$ screening threshold and not used in deriving the control classification itself were entered together into a multivariable ordinal (proportional-odds) logistic regression model with the three-tier Control_Status as the outcome ($N = 150$). The overall model was statistically significant ($\chi^2 = 19.3$, $df = 5$, $p = 0.002$; Nagelkerke $R^2 = 0.073$). Incorrect inhaler technique (adjusted OR = 3.45, 95% CI 1.50-7.97, $p = 0.004$) and unclassified inhaler technique (adjusted OR = 2.84, 95% CI 1.25-6.42, $p = 0.012$), each

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relative to correct technique, and reporting tobacco smoke as a trigger (adjusted OR = 2.33, 95% CI 1.15-4.70, $p = 0.019$) were independently associated with worse asthma control. Family history of asthma (adjusted OR = 1.07, $p = 0.875$) and passive tobacco smoke exposure (adjusted OR = 1.49, $p = 0.257$) were not independently associated with control status once adjusted for the other predictors (Table 6).

Table 6. Multivariable ordinal logistic regression for predictors of asthma control status (three-tier outcome, N=150)

Predictor	Adjusted OR	95% CI	p
Family history of asthma (Yes vs. No)	1.07	0.44 - 2.60	.875
Inhaler technique: Incorrect vs. Correct	3.45	1.50 - 7.97	*.004
Inhaler technique: Unclassified vs. Correct	2.84	1.25 - 6.42	*.012
Passive tobacco smoke exposure (Yes vs. No)	1.49	0.75 - 2.98	.257
Tobacco smoke reported as trigger (Yes vs. No)	2.33	1.15 - 4.70	*.019

OR, odds ratio; CI, confidence interval. Model: proportional-odds cumulative link model; Wald 95% CI. *Statistically significant at $p < 0.05$. Overall model

$$\chi^2=19.3, df=5, p=.002, R^2=.073.$$

As a secondary, sample-size-robust analysis, the same four predictors were re-examined against the collapsed binary outcome (Control_Binary: Controlled/Suboptimally Controlled vs. Uncontrolled). This model was also statistically significant ($\chi^2 = 19.5$, $df = 5$, $p = 0.002$; $R^2 = 0.097$) and produced a consistent pattern of findings: incorrect inhaler technique (adjusted OR = 3.33, 95% CI 1.41-7.87, $p = 0.006$), unclassified inhaler technique (adjusted OR = 2.99, 95% CI 1.29-6.93, $p = 0.011$), and tobacco smoke as a trigger (adjusted OR = 2.30, 95% CI 1.13-4.71, $p = 0.022$) remained independently associated with uncontrolled asthma, while family history of asthma ($p = 0.378$) and passive tobacco smoke exposure

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($p = 0.442$) did not (Table 7). The concordance between the ordinal and binary models supports the strength of inhaler technique and tobacco smoke exposure (as a specific trigger) as independent correlates of poor asthma control in this cohort.

Table 7. Multivariable binary logistic regression for predictors of asthma control status (Controlled/Suboptimally Controlled vs. Uncontrolled, N=150)

Predictor	Adjusted OR	95% CI	p
Family history of asthma (Yes vs. No)	1.55	0.59 - 4.06	.378
Inhaler technique: Incorrect vs. Correct	3.33	1.41 - 7.87	*.006
Inhaler technique: Unclassified vs. Correct	2.99	1.29 - 6.93	*.011
Passive tobacco smoke exposure (Yes vs. No)	1.32	0.65 - 2.71	.442
Tobacco smoke reported as trigger (Yes vs. No)	2.30	1.13 - 4.71	*.022

OR, odds ratio; CI, confidence interval. Model: proportional-odds cumulative link model; Wald 95% CI. *Statistically significant at $p < 0.05$. Overall model $\chi^2 = 19.5$, $df = 5$, $p = .002$, $R^2 = .097$.

Lung function indices (FEV1, FVC, and FEV1/FVC, expressed as % predicted and as z-scores) were not incorporated into the multivariable model. As their inclusion would have restricted the analysis to the 49 children who completed spirometry and introduced substantial collinearity between the % predicted and z-score representations of the same measurement; their relationship to control status is instead reported descriptively via the univariate comparison in Table 5, which showed no significant association.

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4. Discussion

Asthma is a heterogeneous chronic respiratory disease characterized by variable symptoms; in children, it remains a substantial global health problem. Coexisting comorbidities are associated with poor disease control. In this study, asthma control levels were evaluated, focusing on the interplay between environmental exposures and triggers, and allergic comorbidities among 150 pediatric asthma patients in northwestern Libya (predominantly Sabratha, Ajeilat, and Al-Jamil), utilizing a composite control index adapted from the Global Initiative for Asthma (GINA) guidelines.

The primary finding is a high prevalence of poor disease control: 60.7% (n=91) of children had uncontrolled asthma, 30.0% (n=45) were suboptimally controlled, and only 9.3% (n=14) achieved control.

These findings align with observations reported in both local and regional studies. Our observed rate of uncontrolled asthma reflects findings from other Libyan urban centers. A study among Libyan asthmatic adolescents reported that only 24% achieved adequate asthma control (Thabet Ali et al., 2021), while pediatric cohorts in Benghazi and Tripoli similarly documented substantial morbidity, frequent emergency department visits, and low control rates (Elzigallai O. et al., 2020). In Saudi Arabia, pediatric studies reported uncontrolled asthma rates ranging from 59.3% to 60.3% (AL-Jahdali et al., 2013). Similarly, studies in Morocco documented uncontrolled asthma in 53% to 61% of pediatric cohorts (Labyad et al., 2025), and population-based data from Tunisia revealed that less than 8% of asthmatic children met the criteria for well-controlled disease (García-Marcos et al., 2023).

Studies investigating pediatric allergic respiratory diseases in Al-Bayda recorded high burdens of persistent pediatric asthma and allergic comorbidities (Thabet Ali et al., 2021), while clinical assessments in Tripoli demonstrated a strong coexistence of uncontrolled bronchial symptoms alongside allergic rhinitis (Elzigallai O. et al., 2020).

4.1 Inhaler Technique as a Main Independent Determinant

Multivariable ordinal and binary logistic regression models identified incorrect inhaler administration technique as a primary

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independent driver of poor asthma control in our cohort (Adjusted OR 3.45, 95% CI 1.50–7.97, $p=0.004$). In a study evaluating inhaler technique among asthmatic patients seen in emergency department in Saudi Arabia, improper use of inhaler devices was observed in 45% of the patients, which directly correlated with frequent emergency department visits and poor control (AL-Jahdali et al., 2013).

4.2 Passive Smoke Exposure vs. Tobacco Smoke as Trigger to Acute Attacks

Environmental tobacco smoke exposure was reported in 51.3% of children, but it lost statistical significance in the multivariable model ($p=0.257$). However, reporting tobacco smoke as a specific symptom trigger was independently associated with a more than two-fold increase in the odds of uncontrolled asthma (Adjusted OR 2.33, 95% CI 1.15–4.70, $p=0.019$). The statistical significance of tobacco smoke as a direct trigger to acute attacks over a history of exposure to smoke might suggest that children whose airways are hyper-reactive to acute smoke inhalation might represent a highly symptomatic phenotype. Furthermore, it may highlight potential recall or habituation bias when taking routine parental smoking histories in regional surveys.

4.3 Atopic Burden and Environmental Triggers

Our study revealed a high atopic burden, with allergic rhinitis present in 84.0% of children, allergic conjunctivitis in 46.0%, and a family history of asthma in 84.7%. Cold (71.3%) and dust (68.7%) were the most frequent triggers, with winter being the peak exacerbation season (46.7%). The high prevalence of allergic rhinitis in our cohort aligns closely with Libyan data from Tripoli (Elzigallai O. et al., 2020), which reported a high comorbidity rate between allergic rhinitis and asthma in Libyan pediatric cohorts. Sabratha and the western coastal region of Libya experience humid coastal weather, seasonal dust storms (Ghibli), and winter temperature drops. These environmental characteristics favor house dust mite proliferation and cold-induced bronchospasm, consistent with pediatric findings in coastal North African cities (Sellami et al., 2025).

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4.4 Spirometry and Asthma Control

Only 32.7% (n=49) of children in our cohort successfully completed spirometry, primarily due to age limitations. Among those tested, age/height/sex-adjusted GLI-2012 parameters (FEV1, FVC, FEV1/FVC % predicted and z-scores) did not differ significantly across control tiers (all $p > 0.12$). This lack of correlation between baseline spirometry and clinical control is well documented in pediatric literature globally and regionally. Pediatric guidelines, including GINA (Global Initiative for Asthma, 2024), emphasize that baseline resting spirometry in asthmatic children often remains normal during asymptomatic intervals, even in those with poor daily symptom control. Studies evaluating GLI-2012 reference standards in pediatric populations confirm that while z-scores and lower limits of normal (LLN) are crucial for diagnosing fixed airway obstruction and tracking lung growth, daily management and treatment step-up decisions must rely on clinical symptom scores, exacerbation frequency, and adherence rather than single spirometry values.

5. Conclusion

This study highlights a high prevalence of poorly controlled asthma among children in Northwestern Libya. Incorrect inhaler technique seemed to be the strongest independent, and clinically modifiable, determinant of poor control. Tobacco smoke as a symptom trigger was independently associated with uncontrolled disease, suggesting either a distinct hyper-reactive phenotype or limitations in how passive smoking history is routinely captured. Despite a high burden of allergic comorbidity, particularly allergic rhinitis, and a strong family history of atopy, these factors did not independently predict control status. Consistent with international evidence, baseline spirometry in the subset able to perform it did not reflect clinical control status, highlighting that routine lung function testing cannot substitute for symptom-based and exacerbation-based assessment in pediatric asthma management. Taken together, these findings might indicate that inhaler-technique education and structured caregiver training as a possible actionable target for improving asthma control in this setting, alongside closer clinical attention to tobacco smoke exposure as a reported trigger. Given the cross-sectional design and

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the limited subset completing spirometry, prospective and larger multicenter studies are needed to confirm these associations and evaluate the impact of targeted inhaler-technique interventions on long-term asthma control in Libyan children.

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