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Original Research Article

Comparative analysis of persistent pediatric asthma with pulmonary function parameters: a cross-sectional study from South India

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ABSTRACT

Background: Asthma is one of the most common chronic respiratory illnesses in children, causing significant morbidity, absenteeism, and poor quality of life. Despite established guidelines, disparities persist in diagnosis and management, especially in developing regions. Pulmonary function testing remains a crucial tool for assessing airway limitation and disease control, yet its correlation with clinical severity in Indian children is under-reported. Objectives were to compare pulmonary function parameters among children with varying grades of persistent asthma and to examine the association between lung-function indices and disease severity.

Methods: This cross-sectional study was conducted in the Institute of Social Paediatrics, Government Stanley Medical College and Hospital, Chennai, from April 2021 to August 2022. One hundred children aged 6-12 years with persistent bronchial asthma were enrolled consecutively. Spirometry was performed according to ATS/ERS 2019 standards using Indian reference equations, and forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC ratio, and peak expiratory flow rate (PEFR) were recorded. Data were analyzed with ANOVA, Chi-square, and Pearson correlation tests.

Results: Of 100 children, 38% had mild, 35% moderate, and 27% severe persistent asthma. Mean FEV_1 values declined significantly from 86.2±10.4% in mild to 78.5±11.3% in moderate and 67.8±12.5% in severe asthma ($p<0.001$). Similar trends were noted for FVC and FEV_1/FVC ratio. A strong negative correlation was observed between asthma severity and FEV_1 ($r=-0.61$, $p<0.001$) and FEV_1/FVC ($r=-0.57$, $p<0.001$). Poor adherence and exposure to household smoke were associated with lower lung-function scores.

Conclusions: Progressive decline in spirometric parameters with increasing asthma severity underscores the value of routine lung-function monitoring in pediatric asthma management. The study re-affirms that FEV_1 and FEV_1/FVC ratios serve as reliable, objective markers for assessing disease control and should complement clinical grading in children with persistent asthma.

Keywords: Pediatric asthma, Spirometry, Pulmonary function, FEV_1, FEV_1/FVC ratio, South India, Asthma severity

INTRODUCTION

Asthma is a significant childhood chronic respiratory illness with inflammation of airways, hyper-responsiveness of the bronchial, and airflow variability. It is still ranked as one of the highest causes of morbidity, school absenteeism, and poor quality of life among children in world. World health organization estimates that approximately 262 million individuals had asthma in 2019 and this disease led to 4.5 lakh deaths, with children playing a significant role in this international burden of disease.[1] Pediatric asthma remains an increasing trend in the world and in low- and middle-income countries (LMICs), especially India.[2]

The global asthma network (GAN) study indicated that about 3-6 percent of Indian school-going children had wheeze in the last year, but the majority had not been diagnosed or treated adequately.[3] In rural and semi-urban areas, the low rate of diagnosis and a high rate of symptoms indicate the unequal access to healthcare and asthma awareness.[4] Similarly, in South India, the community-based surveys still indicate the lack of difference between the percentage of children reporting asthma-like symptoms and the percentage of children obtaining guideline-based management.[5] This reflects the inclination of under-prescription and inadequate compliance to the inhaled corticosteroid (ICS) therapy observed worldwide.[6]

Pulmonary function remains crucial in diagnosing and monitoring asthma. Airflow limitation and treatment response can be reliably measured using spirometric indices.[7] New modalities such as oscillometry and multiple-breath washout are superior to assess the small-airways but are less practical in normal pediatric practice.[8] It is observed that lung function testing has not been adequately conducted in primary care, resulting in the failure to fully characterize the disease.[6,8]

CP represents a heterogeneous disorder in children with difference in inflammatory endotypes, mostly the T2-high and T2-low, that determine the severity of the disease and corticosteroid sensitivity to the disease.[9] The persistent asthma in children has been known to present a persistent decrease in FEV1/FVC, even in the absence of symptoms, implying persistent airway remodelling.[7,9] Trajectories in poor lung function during childhood predict a chronic pattern of obstructive airway disease in adulthood. Knowledge of these physiological trends in the Indian pediatric population is important for better treatment and to reduce morbidity in the long run.[10]

On this background, our study aims to compare pulmonary function parameters among children with varying grades of persistent asthma attending a tertiary care hospital in South India. The objectives of this study are to generate region-specific evidence that can enhance pediatric asthma management and support early identification of children at risk due to poor disease control.

METHODS

This cross-sectional study was conducted in the Institute of Social Paediatrics, Government Stanley Medical College and Hospital, Chennai, from April 2021 to August 2022. Ethical clearance was obtained from the institutional ethics committee (IEC approval dated 24 March 2021). Written informed consent from parents or guardians and assent from children above seven years were obtained prior to enrolment. Children aged 6-12 years attending the pulmonology clinic (persistent asthma cases) and the general pediatric outpatient department (normal controls) were enrolled consecutively. Selection bias was minimised by recruiting all eligible participants who met the inclusion criteria during the study period. Inclusion criteria were children more than six years with persistent bronchial asthma diagnosed as per GINA guidelines 2021, and age- and sex-matched healthy children without respiratory illness at the time of study. Exclusion criteria included children less than six years, those with global developmental delay, chest wall or spinal deformities, or chronic systemic diseases.

Based on a study assuming mean FEV_1 99.3% in healthy children and 92.9% in asthmatics, with 95% confidence and 80% power, the minimum required sample was 150 subjects (75 each group).[11] After inclusion, each child was trained in proper spirometry technique. Spirometry was performed 30 minutes later using a calibrated computerized spirometer following ATS/ERS 2019 standards. Disposable mouthpieces and nose clips were used for hygiene. At least three acceptable and reproducible manoeuvres were obtained, and the highest FEV_1, FVC, and FEV_1/FVC ratio were recorded. Values were expressed as a percentage of predicted norms for Indian children, adjusted for age, sex, and height. Short-acting bronchodilators were withheld for six hours before testing. To assess functional capacity, a six-minute walk test (SMWT) was performed along a straight indoor corridor. The test was conducted after a short rest period under supervision, with chairs placed along the pathway to manage fatigue. The child's ability to complete the age-appropriate distance was noted.

The primary outcome of the study was the assessment of pulmonary function parameters, including forced expiratory volume in one second (FEV_1), FVC, FEV_1/FVC ratio, and PEFR. The secondary outcomes included the evaluation of functional capacity using the SMWT and the analysis of associations between lung function and factors such as age, sex, nutritional status, and environmental exposures. The exposure variables considered in this study were passive smoking and biomass fuel exposure, along with body mass index (BMI) categories classified according to the world health organization (WHO) standards. Potential confounding variables such as age, sex, and nutritional status were examined for their possible influence on pulmonary function indices, particularly FEV_1 and FVC. Bias control and quality assurance.

All spirometric assessments were performed by a single trained technician using the same device to minimize inter-observer variation. Calibration was verified daily. Children with cough, fever, or exacerbation were tested only after recovery to reduce measurement bias. Consecutive sampling helped prevent selection bias. Environmental exposure and adherence data were obtained from parental interviews to improve validity.

This analysis was derived from the persistent-asthma subset of the larger dataset included in the postgraduate dissertation conducted at our institution. Data were entered in Microsoft excel 2021 and analyzed using IBM SPSS Statistics version 26. Continuous variables were normally distributed and analyzed as mean±SD, asthma severity was classified as mild, moderate, severe per GINA 2024. Differences in pulmonary function parameters (FVC, FEV_1, FEV_1/FVC, and PEFR) across asthma-severity categories were compared using one-way analysis of variance (ANOVA) followed by Bonferroni post-hoc tests. Associations between categorical variables were assessed with the Chi-square test, while Pearson's correlation coefficient was used to determine the relationship between asthma-severity scores and spirometric indices. A $p<0.05$ was considered statistically significant. There were no missing data, no additional sensitivity analyses were performed and all analyses were conducted at a 95% confidence level.

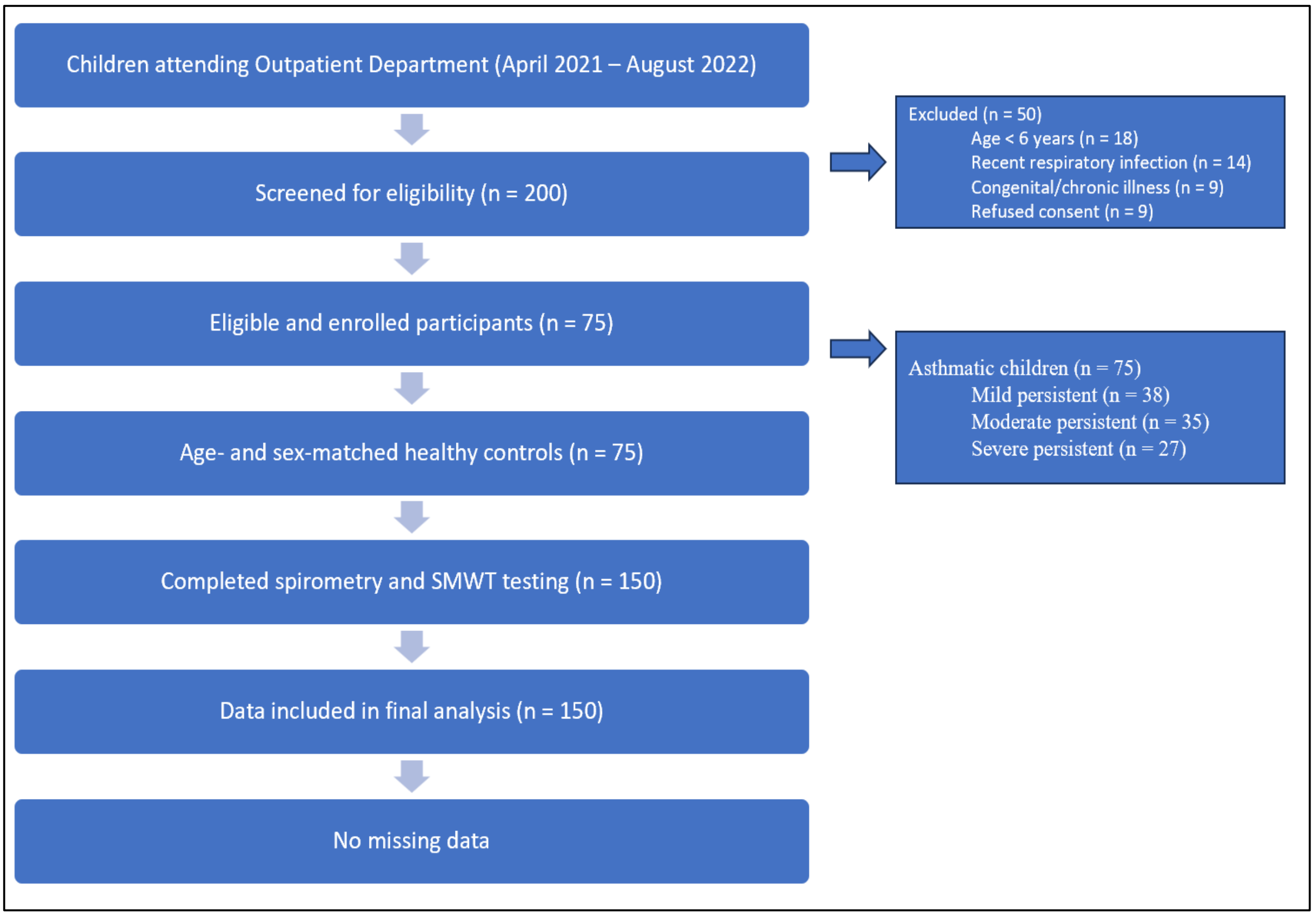

Figure 1: Study flowchart.

RESULTS

A total of 100 children with persistent asthma were studied. Data were complete for all clinical and spirometric variables analyzed. The mean age of participants was 10.3±2.8 years, and 56% were male. Most belonged to the 5-10-year age group. Table 1 presents the demographic and background characteristics.

Most children were urban residents, and nearly half reported a positive family history of atopy. Environmental exposures such as household smoke were common, particularly among rural households.

The distribution of asthma severity and related clinical parameters is shown in Table 2. Mild persistent asthma was the most frequent category (38%), followed by moderate (35%) and severe (27%). Disease duration and nocturnal symptom frequency increased progressively with severity.

Burden from symptoms and activity limitation were significantly higher depending on the extent of disease severity, which indicates the validity of clinical classification.

The adherence pattern and the use of medication are summarized in Table 3. The most common form of therapy consisted of inhaled corticosteroids (ICS), then ICS in combinations with LABA. But compliance came down with greater severity probably due to the socioeconomic and psychosocial impediments.

The highest level of suboptimal adherence was found in the severe group ($p<0.001$), which demonstrates that, despite combination therapy, the control of symptoms is poor.

Table 4 shows the mean parameters of pulmonary functions in the severity groups. It showed progressive changes in FEV 1, FVC, and the FEV 1/FVC ratios. All indices were statistically significant.

FEV1 and PEFR decreased mostly between the moderate and severe groups, demonstrating progressive airway obstruction.

The correlation between demographic variables and mean FEV_1 was shown in table 5.The mean FEV 1 of the males was slightly greater than that of females, without statistical significance. There was a correlation between lower mean FEV_1 with exposure to household smoke and undernutrition but the significance was lost when severity was adjusted.

The exposure to the environment seemed to have an adverse impact on the lung performance regardless of age and gender.

Table 6 Shows high negative correlations between asthma severity score and both FEV 1 (r=-0.61, p<0.001) and FEV 1/FVC (r=-0.57, p<0.001), which indicated that an increase in asthma clinical status is accompanied by a decline in physiological function.

The confirms that with increase in the severity of asthma there was significant decline in the pulmonary function parameters, showing spirometry as a valuable tool for assessing pediatric asthma and its control.

Table 1: Demographic profile and background characteristics of children with persistent asthma, (n=100).

Variables	Category	N (%)
Age group (in years)	≤10	62 (62)
	>10	38 (38)
Sex	Male	56 (56)
	Female	44 (44)
Residence	Urban	61 (61)
	Rural	39 (39)
Family history of asthma/atopy	Present	48 (48)
Exposure to tobacco smoke/ biomass fuel	Yes	41 (41)
Nutritional status (WHO criteria)	Normal	58 (58)
	Undernourished	26 (26)
	Overweight or obese	16 (16)

Table 2: Severity of asthma vs clinical characteristics.

Parameters	Mild (n=38)	Moderate (n=35)	Severe (n=27)	P value
Mean age (in years)	9.7±2.6	10.4±2.9	10.9±2.7	0.18
Duration of asthma (in years)	3.1±1.5	4.0±1.8	4.8±2.2	0.02*
Daytime symptoms (>1/day)	8 (21)	19 (54)	24 (89)	<0.001*
Night awakenings ≥3/week	6 (16)	15 (43)	22 (81)	<0.001*
Activity limitation	5 (13)	14 (40)	21 (78)	<0.001*

*p=0.05=statistically significant

Table 3: Medication and treatment adherence pattern among study participants.

Treatment modality	Mild (n=38)	Moderate (n=35)	Severe (n=27)	Total (%)
ICS alone	25 (65.8)	14 (40.0)	6 (22.2)	45 (45.0)
ICS + LABA	10 (26.3)	16 (45.7)	17 (63.0)	43 (43.0)
LTRA add-on	3 (7.9)	5 (14.3)	4 (14.8)	12 (12.0)
Regular adherence	33 (86.8)	24 (68.6)	12 (44.4)	69 (69.0)

Table 4: Severity of asthma vs pulmonary function parameters.

Parameters	Mild (n=38)	Moderate (n=35)	Severe (n=27)	P value
FVC (% predicted)	90.5±9.7	85.1±10.8	80.2±13.1	0.004*
FEV_1 (% predicted)	86.2±10.4	78.5±11.3	67.8±12.5	<0.001*
FEV_1/FVC (%)	86.8±7.1	79.4±8.5	73.1±9.6	<0.001*
PEFR (% predicted)	88.9±12.0	79.3±11.7	69.6±13.8	<0.001*

*One-way ANOVA with Bonferroni correction.

Table 5: Demographic and environmental factors Vs FEV_1.

Factors	N	Mean FEV_1±SD	P value
Male	56	79.4±12.9	0.28
Female	44	77.0±13.6	
Presence of tobacco/biomass smoke exposure	41	73.9±13.8	0.03*
No exposure	59	81.3±12.0	
Normal BMI	58	80.9±12.1	0.07
Undernourished/overweight	42	76.4±14.3	

*p<0.05=Statistically significant.

Table 6: Clinical severity correlation with spirometric parameters.

Variable pair	Correlation coefficient (r)	P value	Interpretation
Severity score vs. FEV_1	–0.61	<0.001	Strong negative correlation
Severity score vs. FVC	–0.42	0.001	Moderate negative correlation
Severity score vs. FEV_1/FVC	–0.57	<0.001	Strong negative correlation
Severity score vs. PEFR	–0.59	<0.001	Strong negative correlation

DISCUSSION

Our study shows that there was gradual deterioration of the parameters of pulmonary functions with the severity of asthma in children having persistent asthma. Mean FEV_1, FVC and FEV_1/FVC ratio were lower at mild to severe levels, which verifies that physiological impairment is also correlated with clinical severity. Similar trends have been reported in both the Indian and international studies. The same spirometric index diminishing in the same severe phenotypes of asthma in the pediatric group was described by Indolfi et al with the focus on the airflow limitation persisting even when the symptoms were not present.[2] Di Cicco et al also found decreasing FEV_1 and quality-of-life scores with increased severity categories and Balakrishnan et al had almost 18 per cent lower mean FEV_1 between mild and severe cases in South India.[5,9] These observations are concordant, which proves that spirometry is a reliable method to evaluate asthma control.

Our cohort (86.8 percent in mild and 73.1 percent in severe) has a mean FEV_1/FVC ratio that is similar to the one analysed by Gaietto et al in post-COVID pediatric follow-ups.[10] Gianfrancesco et al also established that T2-high and non-T2 inflammatory responses both play a role in fixed obstruction in childhood asthma, a result that can be used to explain the current recurring downward trend of the condition in our regularly treated children.[15] The fact that the poorest medication adherence was seen in a third of the participants is similar to the 30-40 percent adherence rates reported by McCrossan et al and Tang et al.[13,14] Tang et al. emphasized that the wrong parental beliefs and low awareness levels are the main factors that affect the frequent use of inhalers, and McCrossan et al also related poor technique and inconsistent corticosteroid use to poor symptom management. These findings are supported by our results, pointing to the fact that educative and behavioural interventions are still critical in enhancing adherence.[13,14]

The lung function was also affected by environmental factors. Children who experienced biomass fuel or household tobacco smoke had poorer mean FEV_1, in agreement with studies of the Indian community by Balakrishnan et al and Rashmi et al.[4,5] A study conducted by Yuan et al the global burden of disease 2021 analysis, also found indoor air pollution to be a significant cause of asthma morbidity.[1] The pulmonary function had a slight, non-significant nutritional-status correlation. Wang et al. have shown that the relationship between BMI z-scores and spirometric indices is nonlinear and that underweight and obesity both worsen the lung mechanics.[17] Our findings are directed in the same way as this U-shaped pattern, although the smaller sample size can be used as the reason why the results are not significant.

In this study contextual accuracy was maintained by using Indian reference equations. Al-Qerem et al found that spirometric equation derived locally more sensitive in indicating uncontrolled asthma than global lung initiative (GLI) standards.[16] They recommend our course of action since race-neutral equations can be inaccurate when assessing the severity of the disease among South-Asian children. Total intensity of deterioration of air of lungs in our cohort was a little higher than in Western research, perhaps because of the disparities in environmental load, accessibility to healthcare and rate of compliance.[9,15] Di Cicco et al on other hand, observed greater FVC deteriorations, and this may be attributed to fact that they included older adolescents.[9] These small differences could be explained by methodological differences like clinic-based and home-based spirometry (Fan et al) and heterogeneity of population.[12]

There were insignificant sex-wise differences in spirometry, as with Indolfi et al but with slightly lower FEV_1 in females in Wang et al a slightly narrow age range could have reduced the possible hormonal effect.[2,17] The close negative correlation between FEV_1 and asthma severity (r=-0.61) here agrees with the findings of Di

Cicco et al and Boas et al that spirometric deterioration is a reliable indicator of increasing disease burden.[8,9]

Our results can be seen as in large part consistent with published sources of knowledge in heterogeneous populations. Minor discordances are associated rather with the magnitude than the orientation of association, and owe to ethnic and methodological differences. This research augments available evidence that spirometric measurements will always be essential in grading asthma in children, the progression of the disease and the assessment of response to treatment in clinical practice.

Limitations

Our study was conducted in one tertiary-level center and this could be a limitation to the generalizability of the findings to community or primary-care. The cross-sectional design limits the measurement of longitudinal pulmonary changes in pulmonary functions. There is the possibility of recall bias of parental reporting of medication adherence and environmental exposure. There was no measurement of biochemical and inflammatory indicators including eosinophil count or FeNO that could have offered greater information on phenotypic differences. The impact of this research will probably apply to the other tertiary-care and urban pediatric populations of South India, where environmental exposures, socioeconomic status, and health care practices will be similar. Nevertheless, it is also recommended to be careful when extrapolating these findings to the rural or primary-care populations with different living conditions or inaccessibility to diagnostic facilities. The study needs to be multicentric with community-based cohorts and varying geographic region to increase the external validity and set regional reference standards on pediatric lung function in India.

CONCLUSION

Our study shows, children with persistent asthma in this South Indian cohort exhibited a clear decline in pulmonary function with increasing disease severity. The assessment of clinical grading, according to GINA criteria, had a great correspondence with objective spirometric indices, which confirms that it can be useful in the regular practice. Suboptimal compliance and environmental exposures helped to worsen the control whereas residual dysfunction after therapy could be explained by underlying heterogeneity of inflammation. Our paper emphasizes the current role of spirometry in the management and evaluation of pediatric asthma and the necessity of customized, education-focused, and technology-based solutions to managing Indian healthcare facilities.

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