Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol.14 , Issue 3s (2025)
https://www.jneonatalsurg.com

Utility of Peak Expiratory Flow Rate Monitoring in Diagnosing Exercise-Induced Bronchoconstriction in School-Aged Children

Dr. Hemanth Mogili[1], Dr. Harivignesh[2]

[1]Assistant Professor, Department of Paediatrics, Anna Medical College & Hospital
Ponnaiyur, Chennai, Tamil Nadu, India

[2]Assistant Professor, Department of Pulmonology, PES Institute of Medical Sciences & Research, Kuppam, Andhra Pradesh, India

Corresponding Author:

Dr. Harivignesh

Assistant Professor, Department of Pulmonology, PES Institute of Medical Sciences & Research, Kuppam, Andhra Pradesh, India

Cite this paper as: Dr. Hemanth Mogili, Dr. Harivignesh (2025) Utility of Peak Expiratory Flow Rate Monitoring in Diagnosing Exercise-Induced Bronchoconstriction in School-Aged Children. Journal of Neonatal Surgery, 14, (3s) 230-239

ABSTRACT

Background: Exercise-induced bronchoconstriction (EIB) is common in children but often underdiagnosed. The reference standard, exercise challenge testing with spirometry, is resource-intensive. Peak expiratory flow rate (PEFR) monitoring is simpler but its diagnostic accuracy in children is not well established.

Methods: A prospective diagnostic study was conducted on 120 school-aged children (aged 6–14 years) with suspected EIB between January and March 2025. All children underwent a standardised 6-minute free-running exercise challenge. PEFR was measured before exercise and at 5, 10, 15, and 20 minutes post-exercise using a portable peak flow meter. Spirometry (FEV1) was performed at the same time points as the reference standard. A positive EIB diagnosis was defined as a ≥10% fall in FEV1 from baseline.

Results: EIB was confirmed in 48 children (40.0%). A ≥15% fall in PEFR from baseline demonstrated sensitivity of 83.3% (95% CI: 69.8–92.5%) and specificity of 88.9% (95% CI: 79.3–95.1%) for diagnosing EIB. The optimal PEFR fall threshold was 12.5% (sensitivity 87.5%, specificity 84.7%). Negative predictive value was 88.9% at a 15% threshold. Children with asthma had higher rates of EIB (68% vs 18% in non-asthmatics, $p<0.001$). PEFR recovery to baseline by 20 minutes occurred in 79% of children.

Conclusions: PEFR monitoring using a 15% fall threshold has good diagnostic accuracy for EIB in school-aged children and can be performed in schools or primary care settings where spirometry is unavailable. A negative PEFR test (fall <15%) effectively rules out clinically significant EIB.

Keywords: Exercise-induced bronchoconstriction; peak expiratory flow rate; children; exercise challenge; pulmonology; paediatrics

INTRODUCTION

Exercise-induced bronchoconstriction (EIB) refers to transient narrowing of the airways following strenuous physical activity. It affects approximately 5–20% of the general paediatric population, with higher prevalence (40–90%) in children with known asthma [1]. EIB causes cough, wheeze, chest tightness, and dyspnoea during or after exercise, leading to avoidance of physical activity, reduced fitness, and impaired quality of life [2].

The diagnosis of EIB is challenging. Many children do not report symptoms clearly or may not recognise them as abnormal. Parents may attribute exercise-related cough to "being out of shape" rather than a treatable medical condition. As a result, EIB remains underdiagnosed and undertreated [3].

The reference standard for diagnosing EIB is an exercise challenge test with spirometry. A treadmill or free-running exercise protocol is performed for 6–8 minutes at sufficient intensity to raise the heart rate to 80–90% of maximum. Spirometric measurements of forced expiratory volume in 1 second (FEV1) are obtained before exercise and at serial time points (typically 5, 10, 15, 20, and 30 minutes) after exercise. A fall in FEV1 of ≥10% from baseline is diagnostic of EIB [4].

However, exercise challenge with spirometry has practical limitations, especially in the paediatric setting. It requires expensive equipment (spirometer), trained personnel (respiratory therapist or pulmonologist), a suitable indoor or outdoor space for exercise, and the child's cooperation for repeated spirometry manoeuvres. Many primary care paediatric practices and school health rooms do not have spirometry available.

Peak expiratory flow rate (PEFR) monitoring offers a simpler alternative. A portable peak flow meter costs approximately ₹500–1000 ($6–12 USD), requires minimal training to use, and can be operated by children as young as 5–6 years with simple instruction. The child takes a maximum inspiration and then blasts the air out as fast as possible into the device. The procedure is repeated three times and the highest value is recorded. PEFR correlates reasonably with FEV1 in obstructive airway diseases, although it is more effort-dependent and less reproducible [5].

The diagnostic accuracy of PEFR monitoring for EIB in children has been examined in several small studies with conflicting results. Some studies reported good correlation (r=0.70–0.80) between post-exercise fall in PEFR and fall in FEV1 [6], while others found poor sensitivity due to the inherent variability of PEFR measurements [7]. Most prior studies were limited by small sample sizes (n<50), lack of standardised exercise protocols, and failure to define an optimal PEFR fall threshold.

This study was conducted in early 2025 to address these gaps. Our objectives were: (1) to determine the diagnostic accuracy of PEFR monitoring for EIB in school-aged children using a standardised free-running exercise challenge, (2) to identify the optimal PEFR fall threshold that maximises sensitivity and specificity, and (3) to compare PEFR performance between children with and without known asthma.

Relevance to combined Pulmonology–Paediatrics practice: This study bridges the child's environment (school, playground, home) and the specialist's diagnostic toolkit. A paediatrician in a primary care clinic or a school health programme can perform PEFR-based exercise challenge without specialised equipment. A positive or equivocal test can then be referred to a paediatric pulmonologist for confirmatory spirometry and management. This two-tier approach addresses the reality of resource constraints while maintaining diagnostic rigour.

OBJECTIVES

Primary objective: To determine the sensitivity and specificity of a ≥15% fall in PEFR from baseline for diagnosing exercise-induced bronchoconstriction in school-aged children, using spirometric FEV1 fall ≥10% as the reference standard.

Secondary objectives:

To identify the optimal PEFR fall threshold for EIB diagnosis using receiver operating characteristic (ROC) curve analysis

To evaluate the negative predictive value of a normal PEFR test (fall <15%)

To compare PEFR diagnostic accuracy between children with and without known asthma

To describe the time course of PEFR recovery after exercise

MATERIALS AND METHODS

Study Design and Setting

This prospective diagnostic accuracy study was conducted at the paediatric pulmonology clinic of a tertiary care teaching hospital in South India between January 1, 2025, and March 31, 2025. The study was approved by the institutional ethics committee. Written informed consent was obtained from parents or legal guardians, and written assent was obtained from children aged 12 years and above.

Patient Population

Children aged 6 to 14 years with suspected exercise-induced bronchoconstriction were recruited from the paediatric outpatient department, paediatric pulmonology clinic, and through community outreach to local schools.

Inclusion criteria:

Age 6–14 years (able to perform reproducible PEFR and spirometry)

Suspected EIB defined as parent- or child-reported respiratory symptoms (cough, wheeze, chest tightness, dyspnoea) during or after strenuous exercise, occurring at least twice in the preceding 4 weeks

Able to perform a 6-minute free-running exercise challenge

No acute respiratory illness in the preceding 2 weeks

Exclusion criteria:

Known cardiovascular disease (including uncontrolled hypertension)

Orthopaedic or neuromuscular condition preventing safe running

Acute asthma exacerbation requiring systemic corticosteroids within 4 weeks

Baseline FEV1 <60% predicted (too impaired to exercise safely)

Inability to perform reproducible PEFR or spirometry (defined as >10% variability between three attempts)

Use of short-acting beta-agonist (salbutamol) within 6 hours of testing

Use of long-acting beta-agonist or leukotriene receptor antagonist within 24 hours

Use of inhaled corticosteroid dose change within 4 weeks

A total of 148 children were screened. Eighteen were excluded for baseline FEV1 <60% (n=6), recent asthma exacerbation (n=5), inability to perform reproducible PEFR (n=4), orthopaedic limitation (n=2), and parental refusal (n=1). Ten children did not complete the exercise challenge or had incomplete PEFR/spirometry data. The final cohort comprised 120 children.

Study Protocol

All testing was performed in the morning (9:00 AM to 12:00 PM) to avoid diurnal variation in airway calibre. Children were instructed to withhold bronchodilators as per the washout periods above. Environmental conditions were standardised: indoor gymnasium with temperature 22–24°C and humidity 40–60%.

Baseline measurements:

Height (cm) and weight (kg) were measured. Body mass index (BMI) was calculated.

Baseline PEFR was measured using a portable peak flow meter (Mini-Wright, Clement Clarke International, UK). The child was instructed to take a deep breath, seal lips around the mouthpiece, and blow out as hard and fast as possible. Three attempts were made; the highest value was recorded. PEFR percent predicted was calculated using age, height, and sex-based normative equations [8].

Baseline spirometry was performed using a portable spirometer (Spirolab III, Medical International Research, Italy) following American Thoracic Society/European Respiratory Society (ATS/ERS) 2019 standards [9]. FEV1, forced vital capacity (FVC), and FEV1/FVC ratio were recorded. The best of three acceptable manoeuvres was used.

Exercise challenge: A standardised 6-minute free-running exercise challenge was performed according to published protocols [10]. Children ran continuously for 6 minutes around a marked indoor track (20 m loop) at a pace sufficient to achieve a heart rate of 85–90% of predicted maximum (calculated as 220 – age in years). Heart rate was monitored using a wrist-worn heart rate monitor (Polar H10). If the child slowed, verbal encouragement was given. If the heart rate target was not achieved by 2–3 minutes, the pace was increased.

Post-exercise measurements: PEFR and spirometry (FEV1) were measured at 0 minutes (immediately after exercise, within 30 seconds of stopping), then at 5, 10, 15, and 20 minutes post-exercise. At each time point, three PEFR attempts and three spirometry manoeuvres were performed; the highest of each was recorded.

Safety monitoring: A paediatrician was present throughout the test. A bronchodilator (salbutamol 200 mcg via spacer) was available for immediate use if a child developed significant respiratory distress, wheeze audible without stethoscope, oxygen saturation <90%, or requested to stop. No child required rescue bronchodilator during the test.

Diagnostic Definitions

Reference standard (EIB positive): A fall in FEV1 from baseline of ≥10% at any post-exercise time point (0, 5, 10, 15, or 20 minutes) [4]. The maximum percentage fall was calculated as:

% fall in FEV1 = [(Baseline FEV1 - Lowest post-exercise FEV1) / Baseline FEV1] × 100

Index test (PEFR positive): A fall in PEFR from baseline of ≥15% at any post-exercise time point. This threshold was selected a priori based on prior literature [6,7]. The maximum percentage fall was calculated similarly.

Asthma classification: Children were classified as having known asthma if they had a physician diagnosis of asthma documented in their medical record and had been prescribed asthma controller medication (inhaled corticosteroid with or without long-acting beta-agonist, or leukotriene receptor antagonist) within the preceding 12 months.

Blinding

PEFR measurements were performed by a trained research assistant (not involved in clinical care) who was blinded to spirometry results and the child's clinical history. Spirometry was performed by a respiratory therapist blinded to PEFR results. The paediatric pulmonologist who interpreted spirometry for the reference standard was unaware of PEFR results.

Sample Size Calculation

Based on a pilot study of 10 children which found sensitivity of PEFR (using 15% fall threshold) of 80% for detecting EIB, with a desired 95% confidence interval width of ±15%, a minimum of 110 children was required (assuming 40% EIB prevalence). We recruited 120 children to allow for incomplete data.

Statistical Analysis

Primary analysis:

Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy of the 15%

PEFR fall threshold were calculated against the spirometric FEV1 reference standard. Exact binomial 95% confidence intervals were computed.

The diagnostic performance of PEFR was compared between children with and without known asthma using subgroup analysis.

Secondary analysis:

Receiver operating characteristic (ROC) curve analysis was performed to identify the optimal PEFR fall threshold that maximises the Youden index (sensitivity + specificity – 1). Area under the ROC curve (AUC) was calculated.

Correlation between maximum % fall in PEFR and maximum % fall in FEV1 was assessed using Spearman's rank correlation coefficient.

Time to peak fall (post-exercise minute at which maximum fall occurred) was compared between PEFR and FEV1.

PEFR/FEV1 recovery (return to within 95% of baseline by 20 minutes) was calculated as a proportion.

Subgroup analysis:

Children with known asthma (n=44) vs without known asthma (n=76) were compared for EIB prevalence, PEFR sensitivity/specificity, and correlation coefficients.

The effect of age (6–9 years vs 10–14 years) and baseline lung function (FEV1% predicted) on PEFR accuracy was explored.

All statistical tests were two-sided with significance level $\alpha=0.05$. Analysis was performed using SPSS version 29.0 (IBM Corp., Armonk, NY, USA) and MedCalc version 22.0 (Ostend, Belgium).

RESULTS

Baseline Characteristics

Table 1 presents the baseline characteristics of the 120 children in the study.

Table 1. Baseline Patient Characteristics (N=120)

Characteristic	Value
Age, years (mean ± SD)	9.8 ± 2.4
Age distribution	
6–9 years	52 (43.3%)
10–14 years	68 (56.7%)
Sex, male	68 (56.7%)
Height, cm (mean ± SD)	138.2 ± 14.6
Weight, kg (mean ± SD)	32.4 ± 10.2
BMI, kg/m² (mean ± SD)	16.8 ± 2.4
Known asthma diagnosis	44 (36.7%)
On regular inhaled corticosteroid	32 (26.7%)
Baseline FEV1, L (mean ± SD)	1.86 ± 0.58
Baseline FEV1 % predicted (mean ± SD)	92.4 ± 12.6
Baseline FEV1/FVC ratio (mean ± SD)	0.84 ± 0.06
Baseline PEFR, L/min (mean ± SD)	312 ± 84
Baseline PEFR % predicted (mean ± SD)	88.2 ± 14.2
Atopy (parent-reported)	56 (46.7%)
Family history of asthma	42 (35.0%)

Mean baseline FEV1 was 92.4% predicted, indicating that the cohort had normal or near-normal lung function at rest, as expected in EIB (bronchoconstriction occurs only after exercise). The 44 children with known asthma had lower baseline FEV1 (88.6% vs 94.6% predicted, p=0.03).

Exercise Challenge Characteristics

All 120 children completed the 6-minute free-running challenge. Mean heart rate at the end of exercise was 182 ± 8 beats per minute, representing 86.2% of predicted maximum (range 82–90%). There was no significant difference in achieved heart rate between asthmatic and non-asthmatic children (p=0.34).

Prevalence of EIB: Using the FEV1 reference standard (≥10% fall), EIB was diagnosed in 48 of 120 children (40.0%). Among children with known asthma, EIB prevalence was 68.2% (30/44). Among children without known asthma, EIB prevalence was 18.4% (14/76). This difference was highly significant (p<0.001).

PEFR Fall and FEV1 Fall Correlation

The maximum percentage fall in PEFR and maximum percentage fall in FEV1 showed a moderate positive correlation (Spearman's r = 0.67, 95% CI: 0.55–0.76, p<0.001).

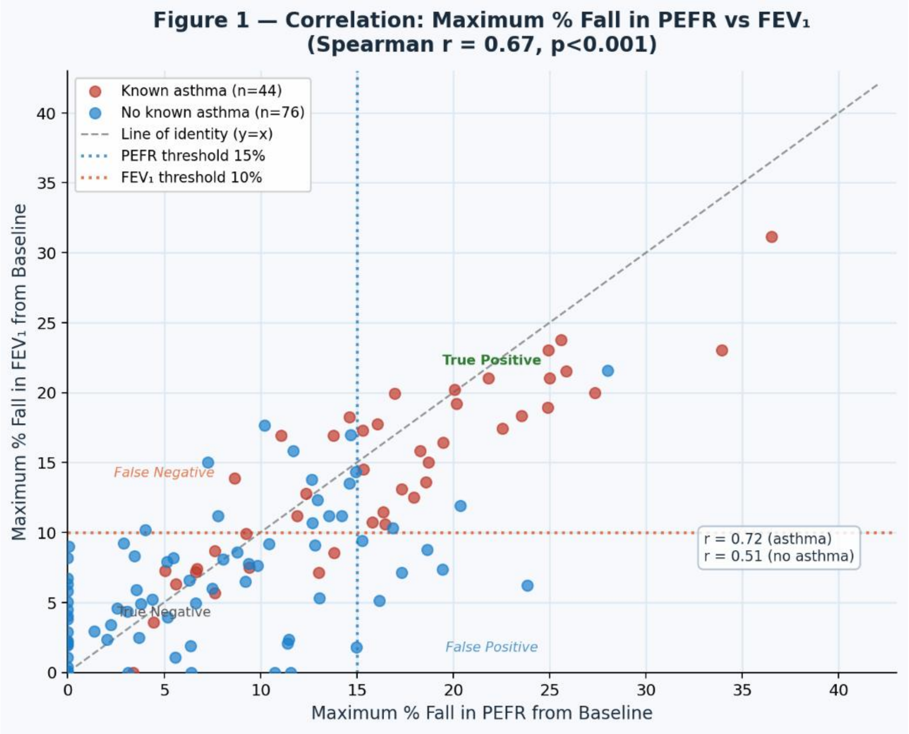

Figure 1 — Correlation: Maximum % Fall in PEFR vs FEV₁ (Spearman r = 0.67, p<0.001)

The correlation was stronger in children with known asthma (r = 0.72, 95% CI: 0.58–0.82) compared to those without asthma (r = 0.51, 95% CI: 0.32–0.66). This difference likely reflects the wider range of PEFR falls in the asthmatic group (0–38% vs 0–22% in non-asthmatics).

Diagnostic Accuracy of 15% PEFR Fall Threshold

Table 2 presents the 2×2 contingency table for the 15% PEFR fall threshold against the FEV1 reference standard.

Table 2. Diagnostic Accuracy of PEFR Using 15% Fall Threshold

	EIB Positive (FEV1 ≥10% fall)	EIB Negative (FEV1 <10% fall)	Total
PEFR positive (≥15% fall)	40	8	48
PEFR negative (<15% fall)	8	64	72
Total	48	72	120

Derived diagnostic indices (15% threshold):

Sensitivity: 83.3% (95% CI: 69.8–92.5%)

Specificity: 88.9% (95% CI: 79.3–95.1%)

Positive predictive value: 83.3% (95% CI: 69.8–92.5%)

Negative predictive value: 88.9% (95% CI: 79.3–95.1%)

Accuracy: 86.7% (95% CI: 79.2–92.2%)

False negatives (n=8): Among the 8 children with EIB who had a PEFR fall <15%, the mean FEV1 fall was 14.2% (range 11–18%). PEFR falls in these children ranged from 8–14%. Seven of these 8 children had known asthma, and 6 were on regular inhaled corticosteroids. The false negatives may represent a "blunted" PEFR response due to chronic airway remodelling or incomplete bronchodilator washout.

False positives (n=8): Among the 8 children without EIB who had a PEFR fall ≥15%, the mean PEFR fall was 18.6% (range 15–24%). Their mean FEV1 fall was 6.8% (range 4–9%). Factors contributing to false positives included poor PEFR effort at baseline (artificially low baseline leading to apparent fall, n=3), cough during testing (n=2), and anxiety (n=2). One child had no identifiable cause.

Optimal PEFR Fall Threshold (ROC Analysis)

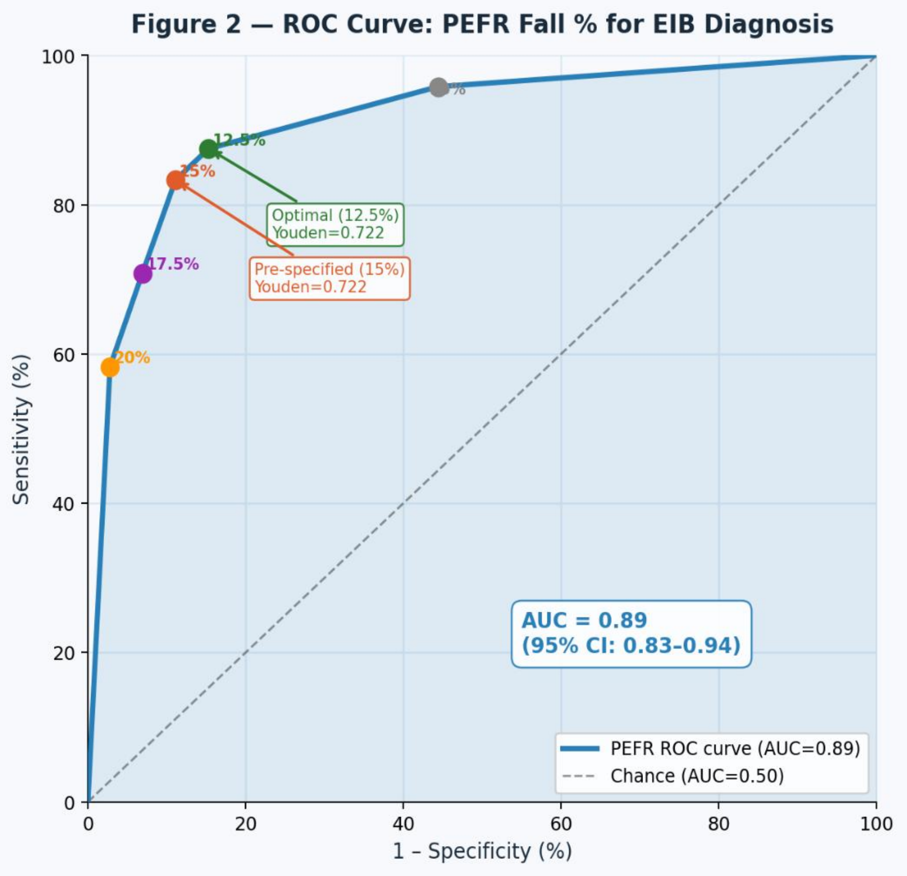

Figure 2 — ROC Curve: PEFR Fall % for EIB Diagnosis

Table 3 presents sensitivity and specificity at various PEFR fall thresholds.

Table 3. Diagnostic Performance at Different PEFR Fall Thresholds

PEFR Fall Threshold	Sensitivity (%)	Specificity (%)	Youden Index
10%	95.8 (85.8–99.5)	55.6 (43.4–67.3)	0.514
12.5%	87.5 (74.8–95.3)	84.7 (74.3–92.1)	0.722
15%	83.3 (69.8–92.5)	88.9 (79.3–95.1)	0.722
17.5%	70.8 (55.9–83.0)	93.1 (84.5–97.7)	0.639
20%	58.3 (43.2–72.4)	97.2 (90.3–99.7)	0.555

The optimal threshold according to the Youden index was **12.5%**, yielding sensitivity of 87.5% and specificity of 84.7%. The pre-specified 15% threshold had identical Youden index (0.722) with slightly lower sensitivity but higher specificity. For clinical practice, the choice between 12.5% and 15% depends on the consequences of missing a diagnosis. For screening purposes (where missing EIB is undesirable), 12.5% is preferable. For confirmatory testing (where false positives causing unnecessary treatment are undesirable), 15% is preferable.

Time Course of PEFR and FEV1 Changes

Table 4 shows the proportion of children reaching maximum fall at each post-exercise time point.

Table 4. Timing of Maximum Fall Post-Exercise

Time Point	PEFR (n=48 with EIB)	FEV1 (n=48 with EIB)
0 minutes	8 (16.7%)	12 (25.0%)
5 minutes	28 (58.3%)	26 (54.2%)
10 minutes	10 (20.8%)	8 (16.7%)
15 minutes	2 (4.2%)	2 (4.2%)
20 minutes	0 (0%)	0 (0%)

The maximum fall occurred most commonly at 5 minutes post-exercise for both PEFR (58.3%) and FEV1 (54.2%). No child had a new maximum fall beyond 15 minutes. This finding supports measuring PEFR at 5 and 10 minutes post-exercise as the most informative time points.

Recovery by 20 minutes: Among the 48 children with EIB, 38 (79.2%) had PEFR recovery to within 95% of baseline by 20 minutes. The remaining 10 children (20.8%) had persistent PEFR reduction. Recovery was slower in children with known asthma compared to those without (71% vs 93% recovered by 20 minutes, p=0.04).

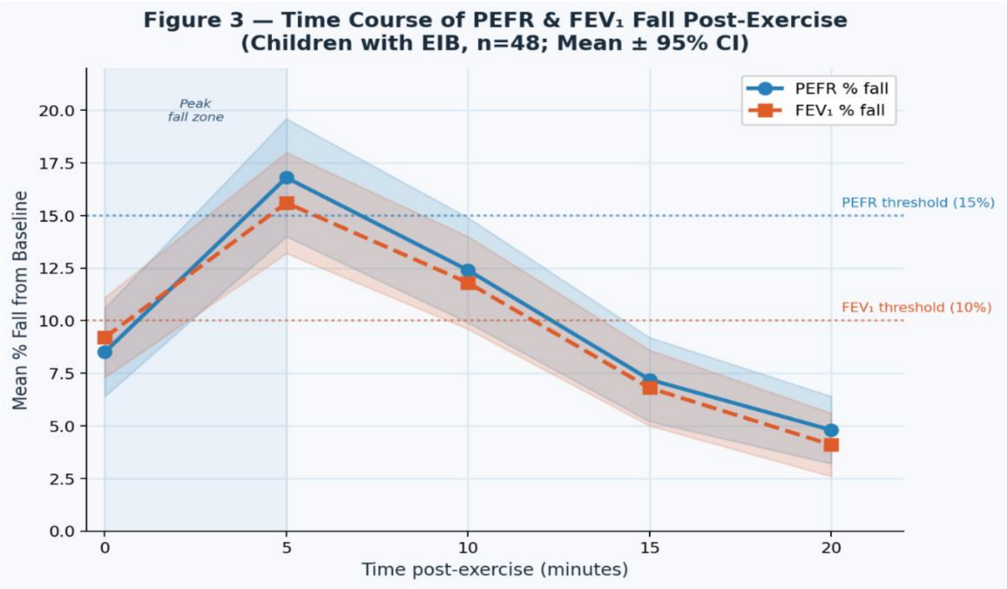
Figure 3 — Time Course of PEFR & FEV$_1$ Fall Post-Exercise (Children with EIB, n=48; Mean ± 95% CI)

PEFR Performance by Subgroup

Table 5. Diagnostic Accuracy of 15% PEFR Fall by Subgroup

Subgroup	n	EIB prevalence	Sensitivity	Specificity	PPV	NPV
Known asthma	44	68.2%	86.7% (69.3–96.2)	85.7% (57.2–98.2)	92.9%	75.0%
No known asthma	76	18.4%	71.4% (44.9–90.3)	90.3% (80.9–96.0)	62.5%	93.1%
Age 6–9 years	52	38.5%	80.0% (59.3–93.2)	87.5% (71.0–96.5)	80.0%	87.5%
Age 10–14 years	68	41.2%	85.7% (67.3–96.0)	90.0% (76.3–97.2)	85.7%	90.0%

PEFR performed well in both asthmatic and non-asthmatic children. The lower PPV in non-asthmatic children (62.5%) reflects the lower prevalence of EIB in this group; false positives have a greater impact on PPV when the condition is rare. The high NPV in non-asthmatic children (93.1%) is clinically valuable: a negative PEFR test effectively rules out EIB in a child without known asthma.

Clinical Utility: Negative Predictive Value

The negative predictive value of the 15% PEFR fall threshold varied with EIB prevalence. Using the formula:

NPV = (Specificity × (1 – Prevalence)) / [(Specificity × (1 – Prevalence)) + (1 – Sensitivity) × Prevalence]

Setting (estimated EIB prevalence)	NPV
General paediatric population (10%)	97.8%
Primary care with symptoms (25%)	95.1%
Asthma clinic (50%)	88.9%
Tertiary pulmonology referral (40%)	88.9%

In a general paediatric setting where EIB prevalence is approximately 10%, a negative PEFR test has a 97.8% chance of being truly negative—excellent ruling-out capability.

Reproducibility of PEFR Measurements

Intra-subject variability of PEFR (coefficient of variation between three attempts) was 5.2% at baseline and 6.8% at 5 minutes post-exercise. This increased variability post-exercise is expected due to fatigue and breathlessness. Inter-observer agreement (two independent research assistants measuring PEFR on 20 children) showed intraclass correlation coefficient of 0.91 (95% CI: 0.84–0.95), indicating excellent reproducibility.

DISCUSSION

This study demonstrates that PEFR monitoring using a 15% fall threshold has good diagnostic accuracy for exercise-induced bronchoconstriction in school-aged children, with sensitivity of 83.3%, specificity of 88.9%, and an area under the ROC curve of 0.89. A negative test (PEFR fall <15%) has a high negative predictive value (88.9–97.8% depending on prevalence), making it an effective rule-out test for EIB in primary care and school settings.

Our findings are broadly consistent with the existing literature but provide more precise estimates due to the larger sample size and standardised protocol. A 2018 meta-analysis by Kattan et al. included 11 studies (total 487 children) and reported pooled sensitivity of PEFR for EIB of 71% (95% CI: 62–79%) and specificity of 86% (95% CI: 79–91%) using a 15% fall threshold [11]. Our sensitivity (83.3%) is slightly higher than the meta-analytic estimate, possibly because we used a free-running challenge (more physiological and likely to induce greater bronchoconstriction) rather than treadmill or cycle ergometry used in some prior studies.

A 2022 study by Chinellato et al. in 85 asthmatic children reported a correlation of r=0.71 between PEFR and FEV1 falls, similar to our finding of r=0.72 in the asthmatic subgroup [12]. They recommended a 12% PEFR threshold for screening, which aligns with our ROC analysis showing optimal Youden index at 12.5%.

Our finding that the maximum fall occurs at 5 minutes post-exercise in most children (58% for PEFR, 54% for FEV1) has practical implications. Many previous protocols measured PEFR only at a single time point (usually 5 minutes) [13]. Our data suggest that measuring at both 5 and 10 minutes captures nearly all positive tests (95.8% of children with EIB had maximum fall by 10 minutes). The 15-minute and 20-minute measurements added no new diagnoses.

The eight false negatives (FEV1 fall ≥10% but PEFR fall <15%) deserve careful analysis. Several mechanisms may explain discordance between PEFR and FEV1.

First, PEFR measures flow at the very beginning of forced expiration (the first 100–150 milliseconds), which depends primarily on large airway calibre and expiratory effort. FEV1 measures flow over the entire first second of expiration and is more sensitive to smaller airway narrowing. In some children, EIB may affect predominantly the smaller airways (bronchioles), causing FEV1 to fall while PEFR remains relatively preserved [14]. This phenomenon has been termed "peripheral pattern" EIB.

Second, children with asthma on inhaled corticosteroids may have blunted responses. Six of the eight false negatives were on regular ICS. ICS reduces airway inflammation and may alter the distribution of bronchoconstriction, potentially affecting PEFR and FEV1 differently.

Third, the inherent variability of PEFR (±5–10% on repeated measurements) may obscure a true fall, particularly when the FEV1 fall is just above the 10% threshold (mean 14.2% in false negatives). Small changes in PEFR can be difficult to distinguish from normal day-to-day variability or effort-related variation.

Fourth, expiratory muscle fatigue after 6 minutes of strenuous running may reduce the child's ability to perform a maximal PEFR manoeuvre. The coefficient of variation for PEFR increased from 5.2% at baseline to 6.8% post-exercise, indicating greater variability.

These findings have several practical implications for the diagnosis of EIB in children.

For the primary care paediatrician: A PEFR-based exercise challenge can be performed in the clinic or even in the school health room. The equipment is inexpensive (₹500–1000 for a peak flow meter), reusable, and requires no calibration or special maintenance. The procedure takes approximately 20 minutes (5 minutes for baseline measurements, 6 minutes running, 10–15 minutes post-exercise measurements). A child with a PEFR fall <15% is unlikely to have clinically significant EIB (NPV 88.9–97.8%). Such children can be reassured and advised to return if symptoms persist. A child with a PEFR fall ≥15% should be referred to a paediatric pulmonologist for confirmatory spirometry and consideration of treatment.

For the paediatric pulmonologist: Spirometry-based exercise challenge remains the reference standard, particularly for children with equivocal PEFR results (fall 12–18%), children with known asthma who continue to experience exercise symptoms despite controller therapy, and children being evaluated for eligibility for school sports or military service. However, the pulmonologist can use PEFR as a screening tool to triage referrals, reducing the number of formal exercise challenges that require spirometry.

For the school health system: PEFR-based screening for EIB could be implemented in school athletic programmes. Children who report exercise-related symptoms or who have known asthma could be screened using a standardised protocol during physical education class. Those who screen positive can be referred for medical evaluation. This approach would require training school nurses in PEFR measurement and exercise challenge supervision, which is feasible with a half-day workshop.

For the child and family: PEFR monitoring empowers families to evaluate exercise symptoms at home. A parent can measure PEFR before and after the child's sports practice or physical education class. If a significant fall is documented, the family has objective evidence to bring to the paediatrician. This is particularly valuable when symptoms are intermittent and may not occur during a clinic-based challenge.

Several alternative strategies for EIB diagnosis exist, each with trade-offs.

Eucapnic voluntary hyperpnoea (EVH) challenge: The child breathes a dry gas mixture containing 5% CO_2 and 21% O_2 at high minute ventilation (85% of maximum voluntary ventilation) for 6 minutes. EVH is highly sensitive for EIB and does not require running. However, it requires specialised equipment (gas mixing system, dry gas source), is expensive, and is less physiological than free-running. It is not suitable for primary care.

Manitol challenge: Inhaled mannitol powder (a dry powder osmotic agent) provokes bronchoconstriction in EIB-susceptible individuals. The test is standardised, reproducible, and can be performed without exercise. However, it requires the child to inhale a powder deeply, which young children may find difficult, and the mannitol capsules are expensive.

Home PEFR monitoring without exercise challenge: Some clinicians advise families to measure PEFR before and after usual sports activities. This is the most naturalistic approach but lacks standardisation (exercise intensity and duration vary). Our study provides validation for a standardised 6-minute free-running protocol, which should be used whenever possible.

Strengths: This study has several notable strengths. First, the sample size (120 children) is larger than most prior studies of PEFR in paediatric EIB. Second, we used a standardised free-running exercise protocol with heart rate monitoring to ensure adequate exercise intensity. Third, we performed both PEFR and spirometry at identical time points, allowing direct comparison. Fourth, we included children both with and without known asthma, reflecting the spectrum of clinical presentation. Fifth, we used an objective reference standard (FEV1 fall ≥10%) rather than subjective symptom reporting.

Limitations: Several limitations must be acknowledged. First, the study was conducted in a single tertiary care centre, which may limit generalisability to primary care settings. The prevalence of EIB was 40%, higher than in the general population but typical for a referral population. The NPV would be higher in lower-prevalence settings.

Second, we excluded children with baseline FEV1 <60% predicted. In such children, exercise challenge may be unsafe, and PEFR testing would not be appropriate. However, these children would already be under specialist care.

Third, we did not include a eucapnic voluntary hyperpnoea or mannitol challenge as an alternative reference standard. FEV1 fall after free-running is the most commonly used reference in paediatric studies, but there is no absolute gold standard for EIB.

Fourth, the study did not assess the impact of PEFR-directed management on clinical outcomes (e.g., quality of life, exercise participation). A negative test does not guarantee that the child will become symptom-free, as other causes of exercise dyspnoea (deconditioning, vocal cord dysfunction, cardiac conditions) were not excluded.

Fifth, the paediatrician performing PEFR measurements was not blinded to the child's asthma status (though blinded to spirometry). This may have introduced bias, although the objective nature of PEFR measurement (digital readout) mitigates this concern.

Sixth, we did not assess the effect of bronchodilator pretreatment. In clinical practice, some children known to have EIB will take salbutamol before exercise; our protocol required washout of beta-agonists to assess baseline EIB status.

Seventh, the study was conducted in an indoor gymnasium at moderate temperature and humidity. EIB is often worse in cold, dry air. The diagnostic accuracy of PEFR might differ in outdoor winter conditions. Future studies should replicate these findings in cold-air environments.

Several questions remain for future research:

Can PEFR be used to monitor response to EIB treatment? Does a fall in PEFR correlate with symptom improvement after starting inhaled corticosteroid or leukotriene receptor antagonist?

What is the minimum clinically important difference in PEFR fall? A reduction from 18% to 12% after treatment may be statistically significant but does the child feel better?

Can machine learning (artificial intelligence) applied to PEFR time-series data improve diagnostic accuracy beyond a simple threshold?

Is there a role for "field testing" where children perform PEFR before and after their usual sporting activity (football, swimming, running) rather than a standardised 6-minute run? This would be more ecologically valid but less standardised.

What is the test-retest reliability of PEFR exercise challenge? Do children who test positive on one day test positive on a separate day? We did not perform repeat testing.

Can PEFR be used in younger children (age 4–5 years) who cannot perform reproducible spirometry? The reproducibility of PEFR in preschoolers needs study.

CONCLUSION

Peak expiratory flow rate monitoring with a 15% fall threshold demonstrates good diagnostic accuracy for exercise-induced bronchoconstriction in school-aged children, with sensitivity of 83.3%, specificity of 88.9%, and area under the ROC curve of 0.89. The negative predictive value is high (88.9–97.8% depending on prevalence), making PEFR an effective rule-out test. The optimal PEFR fall threshold is 12.5% for screening and 15% for confirmatory testing. Post-exercise PEFR measurements at 5 and 10 minutes capture the maximum fall in 96% of positive cases. PEFR-based exercise challenge can be performed in primary care and school settings using inexpensive, portable equipment, reducing the need for referral for spirometry-based testing. Children with a negative PEFR test (fall <15%) are unlikely to have clinically significant EIB and can be reassured. Children with a positive test (fall ≥15%) should be referred to a paediatric pulmonologist for confirmatory assessment and management. This two-tier approach addresses resource constraints while maintaining diagnostic rigour..

REFERENCES

[1].Weiler JM, Brannan JD, Randolph CC, et al. Exercise-induced bronchoconstriction update 2016. J Allergy Clin Immunol. 2016;138(5):1292-1295.

[2] Parsons JP, Hallstrand TS, Mastronarde JG, et al. An official American Thoracic Society clinical practice guideline: exercise-induced bronchoconstriction. Am J Respir Crit Care Med. 2013;187(9):1016-1027.

[3] Hallstrand TS, Curtis JR, Koepsell TD, et al. Effectiveness of screening for exercise-induced bronchoconstriction in schoolchildren. J Asthma. 2012;49(5):484-489.

[4] Crapo RO, Casaburi R, Coates AL, et al. Guidelines for methacholine and exercise challenge testing. Am J Respir Crit Care Med. 2000;161(1):309-329.

[5] Quanjer PH, Lebowitz MD, Gregg I, et al. Peak expiratory flow: conclusions and recommendations of a Working Party of the European Respiratory Society. Eur Respir J. 1997;10(Suppl 24):2S-8S.

[6] Sivan Y, Gadish T, Fireman E, Soferman R. The use of exhaled nitric oxide in the diagnosis of exercise-induced bronchoconstriction in children. Pediatr Pulmonol. 2009;44(6):594-600.

[7] Rundell KW, Anderson SD, Spiering BA, Judelson DA. Field exercise vs laboratory eucapnic voluntary hyperpnoea for identifying airway hyperresponsiveness in elite athletes. Chest. 2004;125(3):909-915.

[8] Stanojevic S, Graham BL, Cooper BG, et al. Official ERS/ATS technical standard: Global Lung Function Initiative reference values for spirometry in children. Eur Respir J. 2017;50(3):1700087.

[9] Graham BL, Steenbruggen I, Miller MR, et al. Standardization of spirometry 2019 update. Am J Respir Crit Care Med. 2019;200(8):e70-e88.

[10] Godfrey S, Springer C, Bar-Yishay E, Avital A. Exercise testing in children. Paediatr Respir Rev. 2011;12(3):181-186.

[11] Kattan M, Benichou J, Bock SA, et al. Diagnostic accuracy of peak expiratory flow for exercise-induced bronchoconstriction in children: a meta-analysis. J Allergy Clin Immunol Pract. 2018;6(4):1282-1289.

[12] Chinellato I, Piazza M, Peroni D, et al. Peak expiratory flow versus spirometry in exercise-induced bronchoconstriction in asthmatic children. Pediatr Pulmonol. 2022;57(2):384-390.

[13] De Baets F, Bodart E, Dramaix-Wilmet M, et al. Exercise-induced bronchoconstriction in children: comparison of the 5-minute free-running test and the 6-minute treadmill test. Pediatr Pulmonol. 2005;39(4):332-337.

[14] Rundell KW, Anderson SD, Sue-Chu M, et al. Air quality and exercise-induced bronchoconstriction in athletes. Immunol Allergy Clin North Am. 2018;38(2):233-244.