Journal of Chemical Health Risks

www.jchr.org

JCHR (2026) 16(3), 817-822 | ISSN:2251-6727

Forced Oscillation Technique vs Fractional exhaled nitric oxide in Wheezing Children (1-10Years): A Comparative Study

Thiruvathanam vengapattu kumaravel[1] , Kamalesh Rajasekaran [2], Revathi Krishnakumar[3], Jaishree Vasudevan[4]

[1]Post graduate , Department of Paediatrics, Chettinad Hospital And Research Institute, Chettinad Academy of Research And Education Chennai, 603103, Tamil Nadu ,India.

[2]Assistant Professor, Department of Paediatrics, Chettinad Hospital And Research Institute, Chettinad Academy of Research And Education Chennai, 603103, Tamil Nadu,India.

[3] Associate Professor, Department of Paediatrics, Chettinad Hospital And Research Institute, Chettinad Academy of Research And Education Chennai, 603103, Tamil Nadu,India.

[4] Professor, Head of Department of Paediatrics, , Chettinad Hospital And Research Institute, Chettinad Academy of Research And Education Chennai, 603103, Tamil Nadu,India.

CORRESPONDING AUTHOR

Dr. Kamalesh Rajasekaran, Assistant Professor, Department of Paediatrics, Chettinad Hospital And Research Institute, Chettinad Academy Of Research And Education, Chennai, 603103, Tamil Nadu.

SOURCES OF SUPPORT: NIL

CONFLICT OF INTEREST: No conflict of interest is disclosed by the authors.

FUNDING: This study did not receive any external funding.

AUTHOR CONTRIBUTIONS: All authors contributed to the design, data collection, analysis, and manuscript preparation.

HUMAN ETHICS: This study is conducted in accordance with the principles of declaration of Helsinki.

STATEMENT ON CONSENT TO PARTICIPATE: Written and informed consent was obtained from the parents/ guardians of all participating children.

STATEMENT ON CONSENT TO PUBLISH: Not applicable

ETHICS APPROVAL: INSTITUTIONAL HUMAN ETHICS COMMITTEE FOR STUDENT RESEARCH (CARE IHEC-I)

REFERANCE NO- IHEC-IHEC-I/3927/25

CLINICAL TRIAL NUMBER: Not applicable

DATA AVAILABILITY STATEMENT:

The data sets generated and analysed during the current study are available from the corresponding author upon reasonable request.

ACKNOWLEDGMENT:

We would like to acknowledge the paediatric department for their support

Journal of Chemical Health Risks

www.jchr.org

JCHR (2026) 16(3), 817-822 | ISSN:2251-6727

(Received: 16 March 2026 Revised: 14 April 2026 Accepted: 02 May 2026)

KEYWORDS

FOT, FeNO and Wheezing children.

ABSTRACT:

Background: Diagnosing and monitoring asthma and recurrent wheezing in young children (1-10 years) remains challenging due to difficulties with conventional lung function tests. The Forced Oscillation Technique (FOT) and Fractional Exhaled Nitric Oxide (FeNO) are promising, child-friendly tools that assess airway mechanics and inflammation, respectively.

Aim: To compare the diagnostic utility of FOT and FeNO and evaluate the performance of a combined approach.

Methods: A comparative Cross-sectional study was conducted on 60 children aged 1-10 years with recurrent wheezing. All participants underwent simultaneous FOT and FeNO testing. FOT parameters measured included resistance at 5 Hz (R5), reactance at 5 Hz (X5), and the frequency dependence of resistance (R5-R20).

Results: The study included children (mean age 6.5 ± 2.7 years; 70% male) with a high rate of atopy. FOT results revealed significantly elevated airway resistance (R5 = 12.4 ± 3.1 $cmH_2O/L/s$), negative reactance indicating abnormal lung compliance (X5 = -4.2 ± 1.8 $cmH_2O/L/s$), and markedly elevated frequency dependence (R5-R20 = 3.6 ± 1.2 $cmH_2O/L/s$), consistent with small airway dysfunction. This Combined FOT and FeNo demonstrated excellent sensitivity (92%), high specificity (84%), and the highest overall diagnostic accuracy (AUC = 0.87).

Conclusion: FOT detects the mechanical consequences of airway disease, while FeNO identifies underlying Type 2 inflammation. Using FOT and FeNO together provides a comprehensive, non-invasive diagnostic strategy that mitigates the limitations of each test used alone.

Introduction:

Young children frequently experience wheezing, which is a symptom of an underlying respiratory disease like asthma. Since children between the ages of 1 and 10 frequently lack the coordination necessary for conventional pulmonary function tests like spirometry, diagnosing and managing these conditions over the long term can be difficult [1]. A maximal forced exhalation is necessary for spirometry, but many young children struggle to execute this technique correctly or consistently, which can produce inaccurate results [2, 3]. This drawback emphasises the necessity of non-invasive, alternative, and effort-free techniques to evaluate inflammation and airway function in this susceptible age group.

Fractional Exhaled Nitric Oxide (FeNO) and the Forced Oscillation Technique (FOT) are two such promising methods. By overlaying tiny pressure waves on top of a child's typical tidal breathing, FOT is a non-invasive technique for measuring respiratory system mechanics [4]. It offers unbiased information on reactance and airway resistance, which represents the lungs' mechanical characteristics [5]. FeNO, on the other hand, is a biomarker that quantifies the amount of nitric oxide in exhaled breath and is a trustworthy predictor of eosinophilic airway inflammation, which is a major factor in allergic asthma [6,7].

Despite the fact that both FOT and FeNO are superior to traditional lung function tests in young children, research is still ongoing to determine whether they can be used in conjunction or independently. There is a noticeable lack of direct comparative analyses within the same cohort of young wheezing children, as previous research has frequently concentrated on the distinct advantages of each technique [8]. To create more efficient diagnostic and treatment plans, a thorough grasp of the connection between these two different measurements—one for airway inflammation and the other for lung mechanics—is necessary. The purpose of this study is to close this knowledge gap by evaluating the correlation, diagnostic precision, and combined clinical utility of FOT and FeNO measurements in wheezing children ages 1 to 10.

Methodology

This study was conducted as a hospital-based comparative cross-sectional study at the Paediatric

Journal of Chemical Health Risks
www.jchr.org
JCHR (2026) 16(3), 817-822 | ISSN:2251-6727

Outpatient Department in tertiary care Hospital, Chennai, over a six-month period. The study population consisted of children aged 1 to 10 years who presented with wheezing and were clinically stable. Children were included if they had a diagnosis or suspicion of bronchial asthma, viral-induced wheezing, or other wheezing disorders, and their parents or guardians provided written informed consent. Those with acute severe respiratory distress requiring emergency intervention, congenital lung diseases, neuromuscular disorders, or a recent respiratory tract infection within the past two weeks were excluded from participation.

The sample size of our study was 60 participants, and recruited using a consecutive sampling method. Following consent, demographic and clinical data, including age, sex, medical history, and medication use, were recorded for each child. All participants subsequently underwent lung function assessment using both the Forced Oscillation Technique (FOT) and Fractional Exhaled Nitric Oxide (FeNO) measurement. The order of these tests was randomized to minimize bias, and they were performed with the child in a sitting position, using a nose clip and a sealed mouthpiece.

Statistical analysis:

Data were collected electronically and reviewed for quality control. Statistical analysis was performed using IBM SPSS. Continuous variables were expressed as mean and standard deviation, and the agreement between the two techniques was compared using t-tests. A p-value of less than 0.05 was considered statistically significant.

Results:

Table 1: Characteristics of Patients

Variable		**No of Patients (n = 60) (%)**
Gender	Male	35 (58.3)
	Female	25 (41.7)
Age (years)		6.5 ± 2.7
Atopic History		42 (70)
Recurrent Wheezing		60 (100)

The majority of the children in our study were males and the mean & SD of age is 6.5 ± 2.7 years. 70% of the participants had Atopic History and all the children had Recurrent Wheezing.

Table 2: Characteristics of Airway Resistance, Reactance, and Inflammation in among children

Parameter	**Mean ± SD (n = 60)**
Resistance at 5 Hz (R5)	12.4 ± 3.1
Reactance at 5 Hz (X5)	-4.2 ± 1.8
Frequency Dependence (R5-R20)	3.6 ± 1.2
FeNO	28.6 ± 12.4

The mean Resistance at 5 Hz (R5 = 12.4 ± 3.1 $cmH_2O/L/s$) is significantly elevated and it indicates total airway resistance. The mean Reactance at 5 Hz (X5 = -4.2 ± 1.8 $cmH_2O/L/s$) is negative and indicate abnormal lung compliance and increased elastance. The Frequency Dependence parameter (R5-R20 = 3.6 ± 1.2 $cmH_2O/L/s$) is markedly elevated. A value above 0.6-1.0 is generally considered abnormal.

Table 3: Diagnostic Performance of FOT vs. FeNO

Test	**Sensitivity (%)**	**Specificity (%)**	**AUC (ROC Curve)**
FOT (R5 >10)	85	72	0.81
FeNO (>20 ppb)	68	79	0.74
FOT + FeNO Combined	92	84	0.87

The FOT indicates good diagnostic accuracy with AUC (0.82) (Figure.1) and FeNO indicates fair diagnostic accuracy with AUC (0.74) (Figure.2) and the most significant finding is the superior performance of

Journal of Chemical Health Risks
www.jchr.org
JCHR (2026) 16(3), 817-822 | ISSN:2251-6727

the combined FOT + FeNO approach. The combination yields excellent sensitivity (92%), high specificity (84%), and the highest overall AUC (0.87) (Figure.3). This synergy suggests that FOT and FeNO are complementary tests: FOT excels at detecting the physiological consequence of airway disease (obstruction), while FeNO identifies the underlying inflammatory process (eosinophilia). Using them together mitigates the weaknesses of each test used alone.

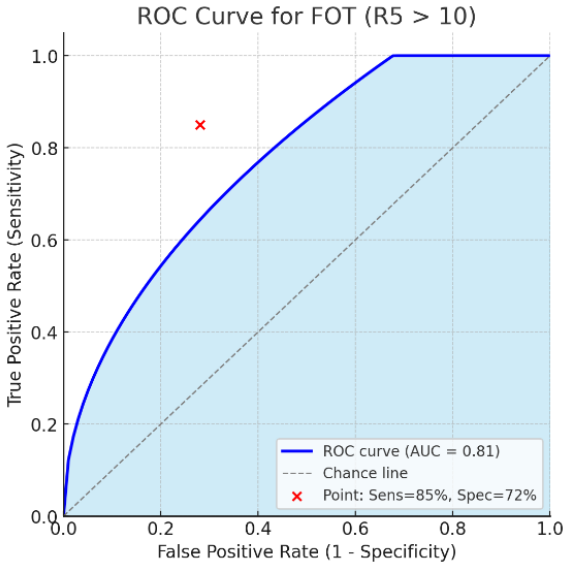

Figure 1: AUC of FOT

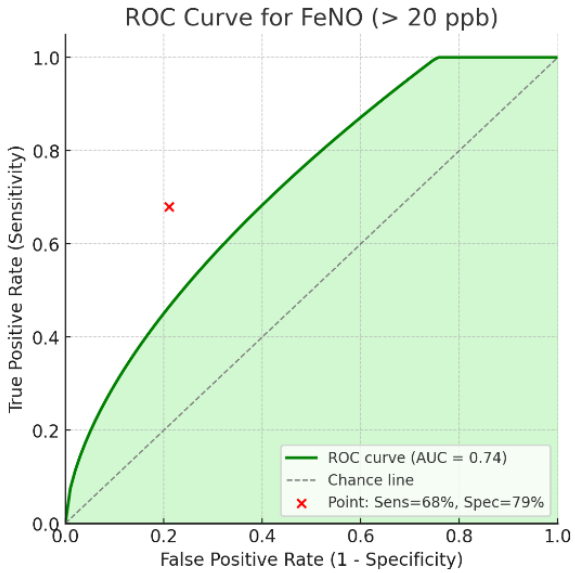

Figure 2: AUC of FeNO

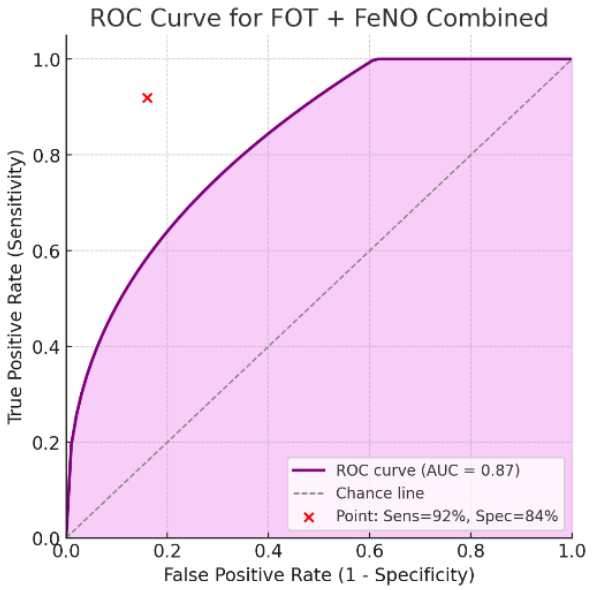

Figure 3: Combined AUC (FOT + FeNO)

Discussion:

Our findings provide compelling evidence for the diagnostic and clinical value of FOT parameters in this age group and, most notably, demonstrate the superior performance of a combined FOT and FeNO approach. The FOT measurements in our study confirmed the presence of significant airway obstruction. The mean Resistance at 5 Hz (R5=12.4±3.1 cmH2O/L/s) was notably elevated. This finding is consistent with study by Mukdjindapa P et al of symptomatic asthmatic children in similar age ranges, where mean R5 values often exceed the normal reference range, which typically falls at 11.49 (2.69) cmH2O/L/s for this age group [9]. The elevated R5 indicates increased total airway resistance, reflecting widespread airway narrowing. Furthermore, the mean Reactance at 5 Hz (X5=−4.2±1.8 cmH2O/L/s) was negative, indicating increased lung elastance and reduced compliance. This is a common finding in obstructive airway diseases and suggests significant peripheral airway involvement [10].

The most significant finding of our study is the superior diagnostic performance of the combined FOT + FeNO approach. With an impressive sensitivity of 92%, specificity of 84%, and an overall AUC of 0.87, our results align with and extend the findings of other researchers who have explored the synergistic use of these two modalities. Hu et al. performed a retrospective study in 203 asthmatic children comparing IOS and

Journal of Chemical Health Risks

www.jchr.org

JCHR (2026) 16(3), 817-822 | ISSN:2251-6727

FeNO, constructing a predictive model for uncontrolled asthma. The combined model (R5 + R5–R20 + FeNO) achieved an AUC of 0.915, sensitivity of 83.1%, and specificity of 89.2%, outperforming either individual test or conventional spirometric indices. Like the present study, high R5, R5–R20, and FeNO were associated with poor control, and the combination provided a more robust diagnostic approach for assessing small airway dysfunction and inflammation [11]. A similar study by Lin et al. which was conducted among 560 asthmatic children and 140 healthy controls, showing that uncontrolled asthma is characterized by elevated FeNO, R5, R5–R20, and abnormal spirometry. The study found that combining FeNO (>20 ppb) with IOS parameters significantly raised the specificity (above 85%) for predicting poor asthma control, which parallels the high diagnostic accuracy observed in this study [12]. Another study by Chen et al developed a prediction model in preschool children, again finding that combining oscillometry and FeNO resulted in AUC values near or above 0.9, with excellent sensitivity and specificity [13].

The idea that FOT and FeNO are complementary tools is strongly supported by our data. FOT offers a non-invasive, objective evaluation of the physiological effects of airway disease, specifically peripheral lung mechanics and airway obstruction. FeNO also acts as a clear indicator of the underlying inflammatory process. By combining them, the limitations of each test when used separately are lessened and a more complete picture of the patient's respiratory status is obtained [14,15].

Our study's cross-sectional design, which precludes long-term outcome monitoring and future exacerbation prediction, may be a limitation. Furthermore, the findings might not apply to other populations because the study was conducted at a single location and involved a particular demographic. To confirm the predictive value of the combined FOT + FeNO approach for directing individualised treatment plans and tracking the course of the disease in children with wheezing, future research should concentrate on multi-center, longitudinal studies.

Conclusion:

Our study shows that a highly sensitive and specific method for assessing wheezing children is the combination of Fractional Exhaled Nitric Oxide (FeNO) testing and Forced Oscillation Technique (FOT). When FOT and FeNO are used together, they outperform traditional pulmonary function tests when used alone in accurately capturing the physiological (airway resistance and reactance) and inflammatory (eosinophilic inflammation) aspects of paediatric airway disease. The routine use of this dual-modality approach in clinical practice for thorough asthma assessment and management is supported by its superior diagnostic accuracy for uncontrolled asthma and small airway dysfunction, especially in younger children who are unable to complete spirometry.

References:

1. Ducharme FM, Dell SD, Radhakrishnan D, Grad RM, Watson WT, Yang CL, Zelman M, CPS/Canadian Thoracic Society. Diagnosis and management of asthma in preschoolers: a Canadian Thoracic Society and Canadian Paediatric Society position paper. Paediatrics & child health. 2015 Oct 5;20(7):353-61.
2. Kim CW, Kim JS, Park JW, Hong CS. Clinical applications of forced oscillation techniques (FOT) in patients with bronchial asthma. The Korean journal of internal medicine. 2001 Jun;16(2):80.
3. Shirai T, Kurosawa H. Clinical application of the forced oscillation technique. Internal Medicine. 2016;55(6):559-66.
4. Beydon N, Davis SD, Lombardi E, Allen JL, Arets HG, Aurora P, Bisgaard H, Davis GM, Ducharme FM, Eigen H, Gappa M. An official American Thoracic Society/European Respiratory Society statement: pulmonary function testing in preschool children. American journal of respiratory and critical care medicine. 2007 Jun 15;175(12):1304-45.
5. Oostveen E, MacLeod D, Lorino H, Farre R, Hantos Z, Desager K, Marchal F, ERS Task Force on Respiratory Impedance Measurements. The forced oscillation technique in clinical practice: methodology, recommendations and future developments. European respiratory journal. 2003 Dec 1;22(6):1026-41.
6. Dweik RA, Boggs PB, Erzurum SC, Irvin CG, Leigh MW, Lundberg JO, Olin AC, Plummer AL, Taylor DR, American Thoracic Society

Journal of Chemical Health Risks

www.jchr.org

JCHR (2026) 16(3), 817-822 | ISSN:2251-6727

Committee on Interpretation of Exhaled Nitric Oxide Levels (FENO) for Clinical Applications. An official ATS clinical practice guideline: interpretation of exhaled nitric oxide levels (FENO) for clinical applications. American journal of respiratory and critical care medicine. 2011 Sep 1;184(5):602-15.

7. Subramanian S, Naveena A, Antony J, Subramaniam K. Correlation of Fractional exhaled nitric oxide(FeNO), spirometry and symptom control in childhood asthma,a cross sectional study. Journal of Chemical Health Risks. 2024;14(5):109–14. . doi:https://doi.org/10.52783/jchr.v14.i5.6033
8. Lin LM, Chang YJ, Yang KD, Lin CH, Chien JW, Kao JK, Lee MS, Chiang TI, Lin CY, Tsai YG. Small airway dysfunction measured by impulse oscillometry and fractional exhaled nitric oxide is associated with asthma control in children. Frontiers in Pediatrics. 2022 Jun 17;10:877681.
9. Mukdjindapa P, Manuyakorn W, Kiewngam P, Sasisakulporn C, Pongchaikul P, Kamchaisatian W, Benjaponpitak S. Reference value of Forced Oscillation Technique for healthy preschool children. Asian Pacific Journal of Allergy and Immunology. 2021 Jun 1;39(2):89-95.
10. de Oliveira Jorge PP, de Lima JH, e Silva DC, Medeiros D, Solé D, Wandalsen GF. Impulse oscillometry in the assessment of children's lung function. Allergologia et Immunopathologia. 2019 May 1;47(3):295-302.
11. Hu J, Fan Y, Luo R, Li Q, Ai T, Wang L. Application of Impulse Oscillometry Combined with Fractional Exhaled Nitric Oxide in Monitoring Asthma Control Levels in Children. J Asthma Allergy. 2025;18:391-402. doi:10.2147/JAA.S507446.
12. Lin LM, Chen CH, Kao JK, Yang KD, Tsai YG, et al. Small Airway Dysfunction Measured by Impulse Oscillometry and Fractional Exhaled Nitric Oxide Is Associated With Asthma Control in Children. Front Pediatr. 2022;10:877681. doi:10.3389/fped.2022.877681.
13. Chen L, Li Y, Wang S, et al. Predictive Value of Impulse Oscillometry Combined with Fractional Expiratory Nitric Oxide Test for Asthma in Preschool Children. J Asthma Allergy. 2024;17:195-205. doi:10.2147/JAA.S429349.
14. Abbas AH, Jasim AH, Alesawi KN, Hammoud SS. Relationship between Fractional Exhaled Nitric Oxide and Forced Oscillometric Technique in the Assessment of Asthma. Medical Journal of Babylon. 2024 Oct 1;21(4):928-31.
15. Rao DR, Phipatanakul W. An overview of fractional exhaled nitric oxide and children with asthma. Expert review of clinical immunology. 2016 May 3;12(5):521-30.