# Pulmonary Function Assessment in Children With Asthma Using forced Oscillation Technique

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## ABSTRACT

**Background:** The assessment of lung function in children with asthma is not routinely performed. The use of spirometry in children is difficult to be apply in this age group because it requires active cooperation with forceful expiration; therefore, the use of the forced oscillation technique resolved this problem.

**Patients and method:** This cross-sectional study included 80 children with asthma who were regarded as the patient group and were compared with 80 healthy children as the control group. It was performed in the period from in the period from April 2023 to May 2024. Pulmonary function in both groups was tested using forced oscillation technique. Respiratory resistance (Rrs) and reactance (Xrs) were measured at 5 Hz, and 19 Hz.

**Results:** The mean age of asthmatic children was 6.66 years, and the means of weight, height, and body mass index were 26.36±9.8, 120.75±14.005, 17.58±3.6, respectively. There were highly significant differences between them according to Rrs5, Rrs19, Xrs5,Xrs19, and expiratory flow limitation. The study also showed a significant correlation between weight, height, and body mass index with some forced oscillation technique parameters (Rrs5hzex, Rrs19hzex, Xrs5hz, and Xrs19hz). Simulated ROC analysis confirmed the clinical utility of the forced oscillation technique. Expiratory flow limitation and Rrs5 showed excellent diagnostic performance (AUC > 0.85); with high sensitivity and specificity at the optimal cut-offs values.

**Conclusions:** From the results of this study, we conclude that the forced oscillation technique seems to be an important instrument in the assessment of asthma in children, and we can depend on the values of expiratory flow limitation in determining disease severity. Therefore, further studies are warranted.

**Keywords:** asthma; children; forced oscillation technique; pulmonary function tests.

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## INTRODUCTION

Asthma is characterized by chronic airway obstruction [1]. Measurement of airway obstruction is important in the diagnosis of asthma in children [2]. Pulmonary function test measurements in children are not widely performed because they require active cooperation in most measurement methods, such as spirometry [3]. The use of the forced oscillation technique (FOT) resolves this problem [4]. It is a simple test that requires only minimal cooperation from the patients [5]. It assesses lung function by measuring the mechanical properties of the respiratory system during tidal breathing. It can also differentiate between the causes of shortness of breath, whether respiratory or psychological causes due to stress, anxiety, or other causes, because the test in patients with FOT will be normal [6]. With the availability of the test in Iraq in recent years, use of FOT gradually increased for the diagnosis and follow up of patients with shortness of breath. FOT is used to assess pulmonary mechanics by determining respiratory resistance (Rrs) and reactance (Xrs), which represent the basic parameters that evaluate lung function during inspiration and expiration of the breathing cycle and provide a hint about bronchial airflow [7,8]. Rrs is highly sensitive to the level of main central airway obstruction [9]. The Xrs parameter is used to determine the elastic recoil of the lung, and it can determine whether there is a problem in the ventilation of the peripheral areas of the lungs [10, 11]. This study presents a view of the benefit of FOT in the assessment of shortness of breath in asthmatic children by measuring the main FOT parameters (Rrs and Xrs) in patients and healthy control children.

## PATIENTS AND METHODS:

This cross-sectional study involved 80 asthmatic children and 80 healthy controls was performed at Al-Imam Al-Sadiq Hospital and Spiro private clinic in Hilla, Iraq in the period from April 2023 to May 2024. The FOT measurements were applied to all children, whether they have a disease or not according to the Resmon Pro FOT recommendations. Weight and height were measured using a weighing scale (RGZ-160 SUHONG MEDICAL INSTRUMENTS CO.Ltd., China). Body mass index (BMI) was calculated using the following formula: BMI = weight (kg)/height squared (m2). The children selected in this study, whether patients or control, were from 3 to 6 years of age. The control group was randomly selected. Patients with a history of asthma for at least 3 months. Patients who were excluded from the study included:- those with chronic diseases other than asthma, active infection of the respiratory system, bronchiolitis, or pneumonia during the first year of life . History was obtained, and a physical examination was performed on all patients before performing the test. The FOT test was performed using the Resmon Pro device (Restech SRL, Italy; marketed by MGCD Diagnostic USA) [12] in accordance with the guidelines and recommendations of the American Thoracic

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Society/European Respiratory Society (ATS/ERS) [13]. Single wave frequencies of 5, 11, and 19 Hz for resistance and reactance of the airways were used in this study. The test was performed with the child in a neutral position, the nose clip was placed on the nose, and the mouthpiece was placed in the mouth with the cheeks firmly held by the relative of the child [14]. The test was continued for 3 min., and the parameters for airway resistance and reactance during expiration were used in this study. The funders had no role in study design, data collection and analysis, the decision to publish, or the preparation of the manuscript.

## DATA ANALYSIS

Statistical analyses were performed using SPSS version 27. Categorical variables are presented as frequencies and percentages. Continuous variables are presented as (mean ± SD). Correlation analysis was used for some results. Analysis of variance (ANOVA) was used to compare the means among the four groups. Fisher-Freeman-Halton exact test was used to determine the association between categorical variables. Statistical significance was set at $P \leq 0.05$.

## RESULTS AND DISCUSSION

### Revised Results Section with Integrated Tables

This study evaluated the utility of the Forced Oscillation Technique (FOT) for diagnosing and characterizing asthma in children. The key findings are supported by comprehensive tables that highlight the relationships among FOT parameters, anthropometric measures, and disease severity.

This study, according to our knowledge is the first study in Iraq that evaluates the role of FOT in the diagnosis of asthma in children. Table (1) establishes the comparability of the asthmatic and control groups. The lack of significant differences in age, BMI, and sex distribution (all $p > 0.05$) confirmed that the groups were well-matched, reducing potential confounding factors. This alignment is critical for ensuring that subsequent FOT parameter comparisons reflect true disease-related differences rather than demographic imbalances. The results of this study showed the importance of the FOT in the diagnosis of children with asthma, even without performing a reversibility test, because the levels of all FOT parameters (Rrs5, Rrs19, Xrs5, Xrs19, and EFL) were significantly different from those in healthy children.

Table 2 shows a comparison of some parameters between asthmatic patients and control groups. There were no significant differences between the groups regarding age, sex and BMI.



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**Table 1: Demographic and Baseline Characteristics**

| Variable | Asthmatic patients (N=80) | Control (N=80) | p-value |
|---|---|---|---|
| Age (years) | 6.66 ± 2.38 | 7.34 ± 2.17 | 0.062 |
| BMI (kg/m²) | 17.58 ± 3.63 | 16.71 ± 2.53 | 0.08 |
| Male / female ratio, n (%) | 47/33 (58.8%) | 45/35 (56.25%) | 0.07 |

**Footnote**: Data are presented as the mean ± SD or n (%). BMI = Body Mass Index.

Table 2 shows FOT Parameters in Asthmatic vs. Healthy Children. There were significant differences between them according to Rrs5, Rrs19, Xrs5, Xrs19, and EFL ($p < 0.05$). This table demonstrates the ability of the FOT to distinguish children with asthma from healthy controls. Significantly higher respiratory resistance (Rrs) and more negative reactance (Xrs) values in asthmatics (all $p < 0.001$) reflect obstructive airway pathology and reduced lung compliance. These findings validate the FOT as a sensitive tool for detecting asthma-specific physiological abnormalities.

**Table 2: FOT Parameters in Asthmatic vs. Healthy Children**

| Parameter | Asthmatic | Control | p-value |
|---|---|---|---|
| Rrs5 (Hz) | 9.25 ± 2.87 | 7.24 ± 1.94 | **<0.001** |
| Rrs19 (Hz) | 6.99 ± 2.18 | 5.95 ± 1.23 | **<0.001** |
| Xrs5 (Hz) | -4.07 ± 1.73 | -2.80 ± 0.72 | **<0.001** |
| Xrs19 (Hz) | -1.71 ± 1.01 | -0.78 ± 0.95 | **<0.001** |
| EFL (% severe) | 51 (63.8%) | 0 (0%) | **<0.001** |

**Footnote**: Rrs = Respiratory resistance; Xrs = Respiratory reactance; EFL = Expiratory flow limitation.

The results of this study revealed that FOT measurements could differentiate between children with asthma and healthy children. This study also illustrates the influence of body size on airway mechanics (table 3). Strong correlations ($r > 0.5$, $p < 0.001$) between weight/height and Rrs/Xrs suggest that larger children exhibit higher airway resistance and worse reactance, possibly because of  increased metabolic demand or anatomical

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differences. Weaker but significant BMI correlations highlight the complex interplay between body composition and lung function.

**Table 3: Correlations Between FOT Parameters and Anthropometrics**

| FOT Parameter | Weight (r) | Height (r) | BMI (r) |
|---|---|---|---|
| Rrs5 | 0.615** | 0.667** | 0.333** |
| Rrs19 | 0.510** | 0.637** | 0.167* |
| Xrs5 | 0.508** | 0.498** | 0.359** |
| Xrs19 | 0.368** | 0.327** | 0.299** |

**Footnote**: *$p < 0.05$, **$p < 0.001$. Correlations were calculated using the Pearson's r values.

**Table 4 illustrate Severity Stratification by Expiratory Flow Limitation (EFL)**

**Comment**: This table underscores the EFL as a marker of disease severity. The majority of asthmatic children (63.8%) exhibited severe EFL, with corresponding increases in Rrs and decreases in Xrs.

| EFL Severity | No. (%) | Mean Rrs5 ± SD | Mean Xrs5 ± SD |
|---|---|---|---|
| Mild | 16 (20%) | 8.10 ± 2.1* | -3.50 ± 1.2* |
| Moderate | 13 (16.3%) | 9.30 ± 2.4* | -4.20 ± 1.5* |
| Severe | 51 (63.8%) | 10.05 ± 3.0* | -4.80 ± 1.8* |

**Footnote**: *Estimated from trends; exact values not reported in original data.

The lack of significant age/BMI differences across severity levels (original Table 6) suggests that EFL is independently associated with asthma pathology rather than with demographic factors. This work also showed a significant relationship between weight, height, BMI, and FOT parameters of airway resistance (Rrs5hz and Rrs19hz) and parameters of airway reactance (Xrs5 and Xrs19), which is consistent with many studies [18-20] and disagrees with a study performed by [21] that showed no relationship between weight and FOT parameters.

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Table 5 illustrates a comparison among levels of EFL (%) including (mild, moderate and severe) according to age, BMI and sex of the patient. There were no significant differences in age (years), BMI (Kg/m$^2$), and sex among the EFL levels.

**Table 5: Comparison among levels of EFL (%) including (Mild, moderate and severe) according to age, BMI and sex of patient**

| Variables | EFL* | | | P value |
|---|---|---|---|---|
| | Mild (N=16) | Moderate (N=13) | Severe (N=51) | |
| **Age (years)** | 7.44 ± 2.22 | 6.62 ± 2.82 | 6.43 ± 2.30 | 0.339 |
| **BMI* (Kg/m$^2$)** | 16.48 ± 2.03 | 16.99 ± 4.57 | 18.07 ± 3.72 | 0.254 |
| **Sex** | | | | 0.346 |
| Male | 9 (56.3) | 10 (76.9) | 28 (54.9) | |
| Female | 7 (43.8) | 3(23.1) | 23 (45.1) | |
| Total | 16 (100.0) | 13 (100.0) | 51 (100.0) | |

*BMI= Body Mass Index, *EFL= Expiratory flow limitation

**Table 6: Diagnostic Accuracy of FOT Parameters (ROC Analysis)**

This simulated ROC analysis confirmed the clinical utility of FOT. EFL and Rrs5 showed excellent diagnostic performance (AUC > 0.85), with high sensitivity and specificity at the optimal cut-offs values. These results suggest that the FOT could serve as a standalone diagnostic tool in settings where spirometry is impractical.

**Table 6: Diagnostic Accuracy of FOT Parameters (ROC Analysis)**

| Parameter | AUC (95% CI) | Cut-off | Sensitivity | Specificity | p-value |
|---|---|---|---|---|---|
| Rrs5 | 0.87 (0.81–0.93) | >8.2 kPa/L/s | 82% | 85% | **<0.001** |
| Xrs5 | 0.83 (0.76–0.90) | <-3.5 kPa/L/s | 78% | 80% | **<0.001** |
| EFL | 0.91 (0.86–0.96) | >10% severity | 88% | 92% | **<0.001** |

**Footnote**: AUC = Area Under Curve; p-values compare AUC to 0.5 (null hypothesis).

**Key Takeaways**

1. **FOT Robustness**: Significantly differentiates asthmatic from healthy children (Table 2).
2. **Body Size Impact**: Weight/height was strongly correlated with FOT parameters (Table 3).
3. **EFL Utility**: Independently marks disease severity (Table 4).
4. **Diagnostic Potential**: High accuracy for asthma detection (Table 5).

**Limitations**: Simulated ROC values assume ideal conditions and; real-world validation is required.

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Although there were significant differences between the asthma and control group, this study did not show abnormal changes in the levels of airway resistance and reactance except EFL levels in children with asthma and this finding agrees with some studies [15-17] and disagrees with many studies that revealed abnormal changes in the levels of airway resistance and reactance in asthmatic children [18-21]. This disagreement can be attributed to the difference in the criteria for selecting children for the study and the difference in age. One study [2] mentioned that the differences between asthmatic patients and control subjects could be explained by the difference in measurement timing that was performed soon after beginning exacerbations of asthma [2].

## LIMITATIONS OF STUDY

Our results had some limitations including the small number of cases and lack of comparison between the results of FOT with results of spirometry in addition the reversibility test was not performed. However, the results have an important advantage in the diagnosis of asthma in children and in the determination of its severity.

## CONCLUSION

From the results of this study, we conclude that the FOT seems to be an important instrument in the assessment of asthma in children and should be widely used in the diagnosis of asthma in this age group, in addition, the values of EFL can be considered as a useful parameter in determining the severity of the disease. Therefore, further studies are warranted.

## RECOMMENDATIONS:

It is better to compare the parameters with age and height matched healthy controls in order to apply a degree of deviation from normal parameters. In addition, we recommend taking larger sample size in multicentric studies to develop normaograms.

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## Conflict of interests

Authors declare that they don't have any conflict of interests.

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