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Impulse oscillometry and spirometry exhibit different features of lung function in bronchodilation

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ABSTRACT

Objective: Bronchodilator responses (BDRs) from impulse oscillometry (IOS) are not interchangeable with those from spirometry. We aimed to identify the characteristics of children with small airway hyperresponsiveness and to determine whether BDR from IOS provides an important supplement to BDR from spirometry. **Methods:** The records of 592 children with asthma or suspected asthma who underwent spirometric and oscillometric BDRs were retrospectively reviewed. Oscillometric BDR was defined as positive when relative or absolute changes of R_{rs5} or X_{rs5} were beyond two standard deviations and spirometric BDR as positive when absolute change of forced expiratory volume in one second (FEV_1) was $\geq 12\%$. Subjects were classified as positive for spirometric BDR only, positive for oscillometric BDR only, positive for both BDRs, or negative for both BDRs. **Results:** The results indicated that 101 (17.6%) subjects were positive for spirometric BDR only, 49 (8.5%) positive for oscillometric BDR only, 48 (8.3%) positive for both BDRs, and 377 (65.6%) negative for both BDRs. The agreement between spirometric and oscillometric BDRs was poor. Baseline FEV_1 , R_{rs5} , and X_{rs5} values strongly influenced the BDRs. Subjects positive for oscillometric BDR only were found to be younger than those positive for spirometric BDR only ($P < 0.001$). Subjects positive for both BDRs were more likely to have asthma, atopic dermatitis, wheezing apart from cold, or decreased baseline lung function relative to those positive in either test ($P < 0.001$). **Conclusions:** There was a low concordance between spirometric and oscillometric BDRs. Use of IOS to detect small airway hyperresponsiveness may add more information about a clinical profile of subjects with asthma.

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Asthma; bronchodilator response test (BDR test); impulse oscillometry system (IOS); spirometry

Introduction

The small airways are a major site of pathology in asthma as the pathological transformation in airway diseases makes the small airways more prone to occlusion (1). Spirometry has been widely used in the clinical setting for the detection of asthma, but has limited value in detecting small airway dysfunction and air trapping (2,3). Furthermore, studies have suggested that the small airways are often engaged early in the course of the diseases, with evident pathologic changes before the onset of symptoms or changes in spirometry and imaging (4). This may be clinically important, particularly when evaluating subjects with normal forced expiratory volume in one second (FEV_1).

The functional assessment of the small airways is acknowledged as a challenging task to clinicians due to

the fact that the distal lung is comparatively unreachable for accurate measurements (5). Recently, the impulse oscillometry (IOS) has been found to quantify the degree of small airways impairments (6,7). Resistance (R_{rs}) is a main parameter of the IOS (8) and detects airway obstruction (8). Reactance of the IOS reflects the elasticity of the peripheral airways (8).

Thus far, there have been several studies that determined the presence of the small airway dysfunction in adults (9,10) and in children with chronic lung diseases (11–15) using the spirometric and oscillometric bronchodilator responses (BDRs). For example, previous studies looking at asthmatic children and nonasthmatic children reported that asthmatic children significantly differed in their oscillometric BDRs through Δ resistance at 5 Hz; however, conventional spirometric BDR was not

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found to be different between groups (13,14). Another study comparing spirometric and oscillometric BDRs in asthmatic and healthy preschool children found that asthmatic children had a significantly higher spirometric and oscillometric BDRs than healthy controls and that there was a significant correlation between spirometric and oscillometric BDRs; however, spirometric BDRs yielded a better diagnostic accuracy of asthma than oscillometric BDRs according to the area under the receiver operating characteristic curve (11). In a recent adult study assessing 50 patients with small airways obstructive pattern determined that a significant spirometric BDR, but not oscillometric BDR, was observed in the study subjects, thus suggesting that oscillometric BDR was of limited value (10). The inconsistent results across various studies may be due to the fact that appropriate reference ranges from a large number of healthy subjects are not established using the oscillometric BDR. In this respect, recent general population studies of adults (16) and children (17) have reported the 95% cutoff values of BDR using the IOS, which may be used for comparison with the spirometric airway reversibility of a 12% change (18). As far as we know, no studies have compared spirometric airway reversibility of a 12% change and oscillometric airway reversibility of the 95% cutoff values of BDR.

The purposes of the present study are to: (i) assess agreement between spirometric and oscillometric BDR results; (ii) define the clinical features of children with small airway hyperresponsiveness, as measured by low-frequency IOS parameters (R_{rs5} and X_{rs5}), and (iii) determine whether oscillometric BDR provides important supplementary information to spirometric BDR using the spirometric airway reversibility of a 12% change and oscillometric airway reversibility of the 95% cutoff values of BDR.

Methods

Subjects

We retrospectively reviewed the medical charts of children (median age: 6.4 years, age range: 5.1–9.3 years) who performed spirometric and oscillometric BDRs at the Pediatric Allergy Clinic of CHA Bundang Medical Center (Yatap-dong, Bundang-gu, Gyeonggi-do, Korea) from November 2012 through December 2014. During the study period, a total of 592 children performed oscillometric or spirometric BDRs. After exclusion of 17 children who did not yield a reliable test result, 575 children were included for the final analysis (Figure 1). This study was approved by the Institutional Review Board of the CHA Bundang Medical Center, CHA University School of Medicine (IRB No. 2016-04-031).

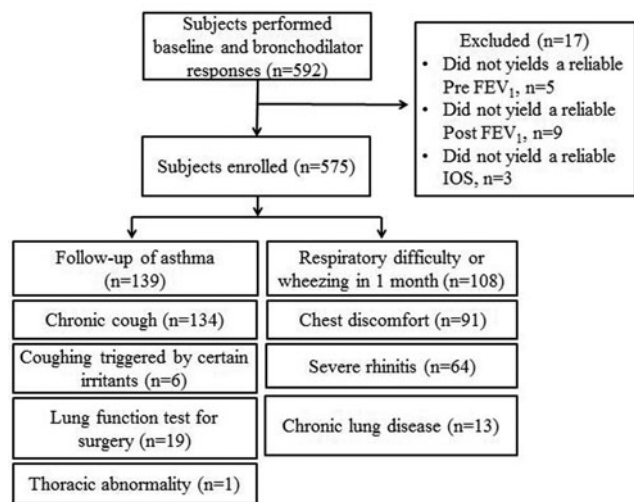


Figure 1. Flow chart of the study subject enrollment.

Lung function measurements

First, baseline values from IOS (R_{rs} and X_{rs}) and spirometry (FEV_1) were measured. If the IOS measurements were reliable (11,19), then spirometry was performed (20); otherwise, spirometry was not performed. For the BDR test, four separate doses of salbutamol (100 μ g) were administered through a spacer, and lung function measurements were repeated in 15 minutes (18). The same technician (Kim SH) performed all BDR measurements. All children were asked to abstain from short acting bronchodilators for 6 h and long-acting bronchodilators for 48 h before these measurements (21).

IOS was performed in accordance with the established guidelines (22). We measured at 5 Hz frequencies, which have a high sensitivity for detecting small airway dysfunction (23). A minimum of three technically acceptable measurements were performed with IOS and spirometry before and after administration of salbutamol, and the means of these measurements were reported. Resistance (respiratory system resistance at 5 Hz [R_{rs5}]) and Reactance (respiratory system reactance at 5 Hz [X_{rs5}]) were measured as a function of frequency. The signals were analyzed for 30s at each frequency (24). Quality control was precisely inspected for both IOS (11,19) and spirometry (20) according to the guidelines. Oscillometric and spirometric tests were performed with a Jaeger MasterScreen device (Jaeger Co., Wurzburg, Germany).

The fractional nitric oxide concentration in exhaled breath (FENO; parts per billion [ppb]) was measured using the CLD 88sp analyzer (CLD88, EcoMedics AG, Switzerland) according to the American Thoracic Society (ATS) guidelines (25).

The Delta (Δ), defined as the difference between pre- and postbronchodilator lung function values, was also measured. BDR was measured as Δ Lung Function

Test (LFT)_{abs} (LFT_{postBDR} – LFT_{preBDR}) and Δ LFT% ($100 \times \Delta$ LFT/LFT_{preBDR}). IOS z scores were used according to previous studies (26–28), and spirometric values were used according to Quanjer et al (29). A positive oscillometric response was defined as a Δ % of 34% or more in Rrs₅ or 50% or more in Xrs₅; Δ abs as a -0.29 kPa/L/s or more change in Rrs₅ or 0.18 kPa/L/s or more change in Xrs₅ following administration of salbutamol (16,17). A positive spirometric response was defined as a 12% or more increase in FEV₁ following administration of salbutamol (18). The study subjects were classified into those positive for both BDRs, those negative for both BDRs, those positive for spirometric BDR only, and those positive for oscillometric BDR only.

Potential determinants of bronchodilator response

Each subject's past and family history were selected as potential determinants of spirometric and oscillometric BDR results, along with baseline lung function measurements. This assessment used a structured questionnaire that assessed personal history of asthma, allergic rhinitis, atopic dermatitis, wheezing apart from cold, and family history. Questions on ER visits in the previous year and hospitalization due to asthma exacerbation were added two years after initial enrollment; as a consequence, fewer subjects had data for these variables. Body mass index (BMI) and BMI z scores were calculated for each subject. The frequency of wheezing episodes apart from cold was classified as frequent (i.e., when parents reported that their child had had four or more attacks of wheezing and/or four or more attacks of dyspnea apart from cold during the last 12 months), infrequent (i.e., when parents reported wheezing apart from cold, but no frequent wheezing episodes were reported), and none (30).

Statistics

Data are expressed as mean $\pm$ SD when normally distributed, and as median (interquartile range [IQR]) when nonnormally distributed. An analysis of variance (ANOVA) was used to compare three groups of continuous variables with normal distributions, and the least significant difference (LSD) test was used for *post hoc* analysis. For categorical variables chi-square testing was conducted. BDR values are presented as median (IQR). The Kruskal–Wallis test was used for comparisons between groups, and Dunn's multiple comparison test for *post hoc* analysis. Agreement between spirometric and oscillometric BDRs was analyzed after calculating the observed and expected proportion of positive and negative agreements and kappa (κ) coefficients (31). Kappa statistics were used to determine the concordance

between spirometric and oscillometric BDRs. In this analysis scheme, a kappa of >0.75 represented excellent agreement, 0.40 – 0.75 represented a fair to good agreement, and <0.40 was indicative of poor agreement (32). The correlation of Δ FEV₁ with Δ Rrs₅ and Δ Xrs₅ was determined using multivariate linear regression analysis, with adjustment for sex, age, and height. The risk factors for BDR were determined using generalized linear regression analysis after adjustment for the confounding factors such as height, sex, and BMI z score.

Results

We retrospectively classified 575 children (median age: 6.4 years, age range: 5.1–9.3 years) according to reasons for BDR testing at our institution. Table 1 shows the clinical characteristics of the study subjects. Twenty-eight children (6.7%) had low birth weight, 41 (9.9%) were prematurely born, 13 (2.2%) were obese (BMI z score ≥ 2), and 25 (4.2%) were underweight.

Agreement between spirometric and oscillometric BDR results

One hundred one subjects (17.6%) were positive for spirometric BDR only and 49 (8.5%) were positive for oscillometric BDR only (Table 2). There were significant

Table 1. Basic demographic and clinical characteristics of study subjects ($n = 575$).

Variable	N*	Median (IQR) or N (%)**
Age, years	575	6.4 (5.1–9.3)
Sex, male	575	338 (57.1%)
Height, m	575	1.20 (1.09–1.34)
Birth weight, kg	415	3.2 (2.9–3.5)
BMI z score	415	0.05 (–0.75–0.65)
Biomarkers		
TEC, cells/mm ³	242	2.6 (1.3–5.3)
Total IgE, kU/L	178	159.7 (57.8–468.3)
FENO, ppb	217	7.2 (4.6–17.1)
Allergic sensitization	496	335 (67.5%)
Family history		
Parental asthma	456	46 (10.1%)
Parental allergic rhinitis	456	253 (55.5%)
Parental atopic dermatitis	456	34 (7.5%)
Past history		
Asthma	448	158 (35.3%)
Wheezing apart from cold	448	143 (31.9%)
Allergic rhinitis	450	240 (53.3%)
Atopic dermatitis	444	76 (17.1%)
Emergency room visit in previous year	308	52 (16.9%)
Asthma admission in previous year	309	16 (5.2%)
Environmental factors		
Secondhand smoking	438	76 (17.4%)
Smoking during pregnancy	413	75 (18.2%)
Pet ownership	440	39 (8.9%)

*Number of subjects for whom data were available.

**Data with nonnormal distributions are shown as median (interquartile range), and data with normal distribution as n (%).

Abbreviations here and below: AR, allergic rhinitis; AD, allergic dermatitis; BMI, body mass index; FENO, fractional nitric oxide concentration in exhaled breath; IQR, interquartile range; TEC, total eosinophil count.

Table 2. Spirometric and oscillometric bronchodilator response results of study subjects ($n = 575$).

Variable	Subjects negative for both BDRs	Subjects positive for spirometric BDR only	Subjects positive for oscillometric BDR only	Subjects positive for both BDRs	P value
N (%) or Median (IQR)					
N	377 (65.6)	101 (17.6)	49 (8.5)	48 (8.3)	
Age, years	7.7 (3.3)	7.8 (3.0)	5.2 (2.0)*†	6.2 (2.6)*†	<0.001
Sex, male	205 (54.4)	67 (66.3)	32 (65.3)	22 (45.8)	0.038
Height, m	1.26 (0.20)	1.26 (0.19)	1.10 (0.13)*†	1.16 (0.17)*†	<0.001
BMI z score	−0.02 (1.10)	−0.17 (1.05)	−0.01 (1.01)	−0.19 (0.99)	0.512
Distribution of reasons for BDR, n (%)					<0.001
Asthma control status, $n = 139$	75 (54.0)	37 (26.6)	6 (4.3)	21 (15.1)	
Chronic cough, $n = 134$	97 (72.4)	21 (15.7)	13 (9.7)	3 (5.5)	
Wheezing in the previous month, $n = 108$	61 (56.5)	14 (13.9)	15 (13.9)	17 (15.7)	
Chest discomfort, $n = 91$	67 (73.6)	13 (14.3)	6 (6.6)	5 (5.5)	
Severe rhinitis, $n = 64$	48 (75.0)	10 (15.6)	5 (7.8)	1 (1.6)	
Operation, $n = 19$	16 (84.2)	2 (10.5)	1 (5.3)	0 (0)	
Chronic lung disease, $n = 13$	9 (69.2)	2 (15.4)	1 (7.7)	1 (7.7)	
Coughing triggered by certain irritants, $n = 6$	4 (66.7)	1 (16.7)	1 (16.7)	0 (0)	
Chest deformity, $n = 1$	0 (0)	0 (0)	1 (100.0)	0 (0)	
Biomarkers					
TEC, cells/mm ³	2.4 (1.3–4.9)	4.0 (2.0–5.9)	1.9 (1.0–3.4)	3.0 (0.9–6.1)	0.068
Total IgE, kU/L	146.5 (44.5–450.6)	222.5 (71.8–810.4)	191.4 (58.0–383.9)	163.6 (133.1–855.6)	0.118
FENO, ppb	6.9 (4.6–15.5)	13.5 (5.2–28.9)*	5.4 (4.1–8.2)	9.7 (4.4–19.1)	0.026
Allergic sensitization	210 (65.0)	28 (67.4)	32 (71.1)	35 (83.3)	0.113
Past history					
Asthma	86 (30.4)	34 (45.9)*	13 (31.7)*	19 (54.3)*‡	0.006
Wheezing apart from cold	82 (29.1)	26 (35.1)*	15 (35.7)*	18 (51.4)*‡	0.054
Allergic rhinitis	156 (54.5)	43 (58.9)	18 (43.9)	17 (48.6)	0.419
Atopic dermatitis	43 (15.2)	10 (13.7)*	7 (17.1)*	12 (35.3)*‡	0.025
ER visits in previous year	22 (11.3)	10 (20.8)*	6 (20.7)*	10 (37.0)*	0.004
Environmental factors					
Secondhand smoking	51 (17.8)	14 (18.9)	6 (14.0)	5 (14.3)	0.862
Smoking during pregnancy	48 (17.7)	15 (22.1)	7 (16.7)	5 (15.6)	0.817
Pet ownership	22 (7.6)	9 (12.2)	3 (7.0)	5 (14.3)	0.392

The analysis of variance (ANOVA) was used for comparison of continuous variables such as age, height, and BMI z score; the LSD was used for *post hoc* analysis.

*indicates $P < 0.05$ compared with subjects negative for both BDRs.

†indicates $P < 0.05$ compared with subjects positive for spirometric BDR only.

‡indicates $P < 0.05$ compared with subjects positive for oscillometric BDR only.

FEV₁, forced expiratory volume in 1 second; IOS, impulse oscillometry; BMI, body mass index; BDR, bronchodilator response; TEC, total eosinophil count; FENO, fractional nitric oxide concentration in exhaled breath; ER, emergency department.

correlations between the Δ FEV₁% values from spirometry and the Δ Rrs₅% and Δ Xrs₅% values from IOS (FEV₁ vs. Rrs₅: $\rho = 0.328$; FEV₁ vs. Xrs₅: $\rho = 0.357$; $P < 0.001$ for both comparisons). There were also significant correlations of Δ FEV₁% with Δ Rrs_{5abs} ($\rho = 0.322$, $P < 0.001$) and Δ FEV₁% with Δ Xrs_{5abs} ($\rho = 0.392$, $P < 0.001$) (Figure 2A and B). However, the kappa coefficient for the agreement between subjects positive for spirometric BDR only and those positive for oscillometric BDR only yielded a poor value (kappa coefficient = 0.234, 95% CI: 0.144–0.324, $P < 0.001$). After adjustment for confounding variables, the risk factors for Δ FEV₁% were pre FEV₁ ($B = -0.892$, $SE = 0.113$, $P < 0.001$) and pre Xrs₅ ($B = -1.317$, $SE = 0.418$, $P = 0.002$). On the other hand, pre Rrs₅ was a risk factor for Δ Rrs₅% ($B = 1.207$, $SE = 0.213$, $P < 0.001$) and pre Xrs₅ was a risk factor for Δ Xrs₅% ($B = -1.106$, $SE = 0.318$, $P = 0.001$).

Clinical characteristics of children with different spirometric and oscillometric BDR results

Subjects positive for both BDRs were more likely to have asthma ($P = 0.006$), wheezing apart from cold

($P = 0.054$), or atopic dermatitis ($P = 0.025$) than those in the other three groups. Subjects positive for oscillometric BDR only were younger than those positive for spirometric BDR only ($P < 0.001$) (Table 2). After adjustment for sex, age, and BMI z score, only subjects positive for spirometric BDR only had a higher FENO value than those negative for both BDRs ($P = 0.049$) (data not shown).

Baseline lung function of children with different spirometric and oscillometric BDR results

Baseline lung function measures had a significant effect on spirometric and oscillometric BDR results (Figure 3). In particular, subjects positive for both BDRs were more likely to have decreased baseline lung function measures than those negative for both BDRs and those who were positive in either test ($P < 0.05$ for all comparisons). In addition, subjects positive for oscillometric BDR only were more likely to have decreased baseline Rrs₅ and Xrs₅ than those negative for both BDRs or those positive for spirometric BDR only. Subjects positive for spirometric BDR only were more likely to have decreased baseline FEV₁ values than those negative for both BDRs.

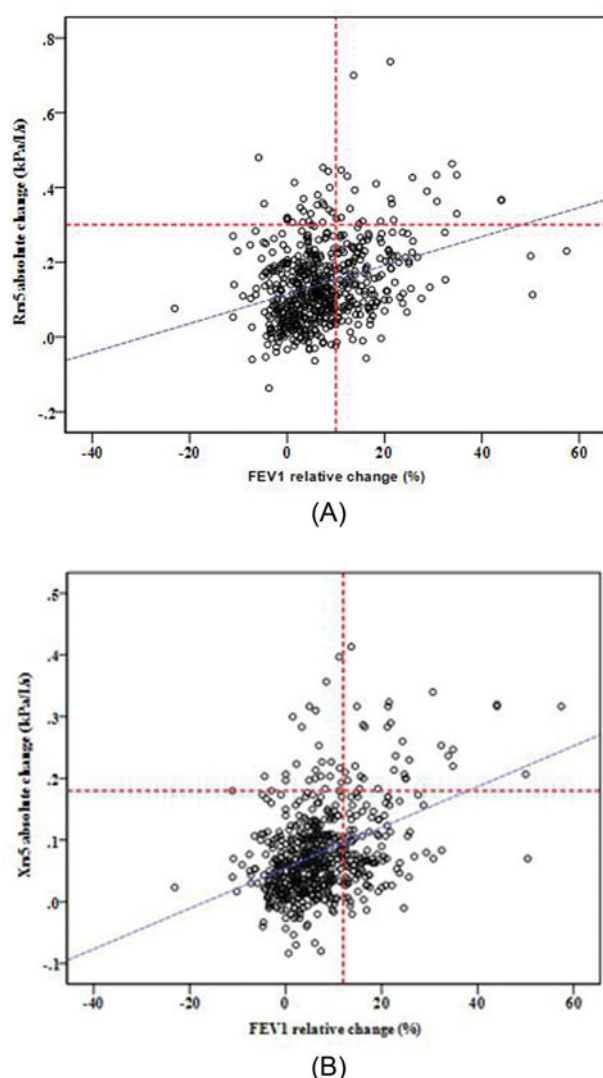


Figure 2. Correlation between relative changes in spirometry and absolute changes in IOS before and after administration of a bronchodilator. (A) Correlation between relative changes in FEV₁ and absolute changes in Rrs₅ before and after administration of a bronchodilator ($\rho = 0.328$, $P < 0.001$). (B) Correlation between relative changes in FEV₁ and absolute changes in Xrs₅ before and after administration of a bronchodilator ($\rho = 0.357$, $P < 0.001$).

Discussion

The aim of the present study of children was to determine whether oscillometric BDR data provides important supplementary information to spirometric BDR data. We confirmed that oscillometric and spirometric BDR results should not be used interchangeably as they measure different aspects of lung mechanics. Children (particularly younger children) with small airway hyperresponsiveness and a positive spirometric BDR were more likely to have decreased baseline lung function measures, asthma, atopic dermatitis, or wheezing apart from cold. The baseline FEV₁, Rrs₅, and Xrs₅ values significantly influenced the BDR changes in these values. Thus, we speculate that

these three parameters may characterize different aspects of lung mechanics. Considering that FEV₁ results may not identify all children with bronchial hyperresponsiveness (5,23,33), and that there is no simple correlation between asthma-like symptoms and objective measures of airway obstruction, IOS and spirometry data may both be useful for the characterization of asthma in children, particularly younger children (11). Based on this finding, we speculate that oscillometric BDR results are a useful supplement to spirometric BDR results and add more information on a clinical profile of asthma.

Importance of clinical information from oscillometric BDR results

A low concordance was observed between spirometric and oscillometric positive BDR results. This finding may be ascribed to the notion that IOS characterizes different physiological features than spirometry (5,9,34,35). Spirometry reflects airflow characteristics (8), mainly measures central airway caliber (4), and is dependent on lung volumes, elastic recoil, strength of respiratory muscle, and expiratory breathing maneuvers (36,37). On the other hand, the IOS assesses airway caliber (8) and measures small airways function and effort- and respiratory muscle-independent lung function. In this regard, previous studies have shown that measures of oscillometric BDR are not interchangeable with those of spirometric BDR (12) and thus it may be unreasonable to directly compare the two test results. Hence, we used the 95th percentile cutoff values of changes in oscillometric BDR using healthy subjects. Previous research have reported that the correlation between spirometric and oscillometric BDR data is relatively low (5,9,11,13,14,21,23). In addition, baseline lung function measures significantly affect airway hyperresponsiveness (18). Thus, subjects with decreased baseline FEV₁ values are more likely to have positive spirometric BDR results (18), and those with decreased baseline IOS parameters are more likely to have positive oscillometric BDR results (17,38,39). This may explain the current finding that subjects with positive results to both BDR tests had decreased baseline lung function measures and clinical characteristics of typical asthma when compared with those who were positive in either test.

Interpretation of oscillometric BDR results

In general, spirometric BDRs in patient-based studies are somewhat higher than those in epidemiologic studies (18). In contrast, some researchers have reported that the oscillometric airway reversibility of a cut-off value from epidemiologic studies (16,17) is higher than that from

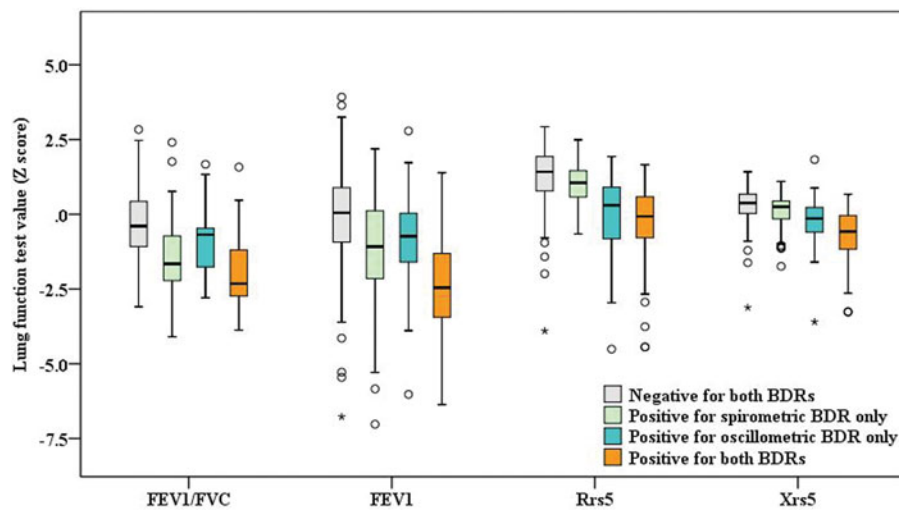


Figure 3. Comparison of baseline FEV₁/FVC, FEV₁, Rrs₅, and Xrs₅ values in subjects with different spirometric and oscillometric bronchodilator response results. Center lines indicate medians, boxes indicate lower and upper quartile, bars indicate smallest and largest values (no greater than 1.5 times the interquartile range), open circles indicate outliers (1.5 and 3 times the IQR), and asterisks indicate extreme values.

case-control studies (11,14,22,40). This may be because epidemiologic studies of the IOS have differentiated a small number of subjects with small airway hyperresponsiveness with a higher cut-off change. Reviewing the distribution of airway hyperresponsiveness beyond two standard deviations, we found that the current study may have used reference values higher than the actual values. This may have resulted in the high specificity of oscillometric BDRs and the low percentage of subjects with positive oscillometric BDR results when compared with those with positive spirometric BDR results. In addition, airway hyperresponsiveness is an integrated physiological response that is related to bronchial smooth muscle, airway epithelium, nerves, and mediators (18). Considering that asthma is a heterogeneous disease (41–43), this may lead to arbitrary diagnoses of asthma; therefore, case-control studies comparing spirometric and oscillometric BDR are of limited value (21,23).

Of note, the subjects positive for spirometric BDR only had a higher FENO value than those negative for both BDRs. This finding may be ascribed to the notion that the spirometric BDR of children with asthma reflects the inflammatory status of the large airways, as measured by a higher FENO level (44) and that the IOS at 5 Hz utilized in the current study does not correlate with the FENO value of the large airways (45), although there are methods available to measure alveolar nitric oxide concentration, maximal nitric oxide flux in the conductive airways, and the N₂ phase III slope of single breath N₂ washout (delta N₂) accurately assessing the inflammation in the small airways (45). This may also explain the current finding that there was no difference in Th2 biomarkers such as TEC and total IgE levels between groups.

The subjects positive for oscillometric BDR only were younger than those in the other groups. It is possible that spirometric results may have been affected by the undercooperation of the forced expiratory maneuvers in young children (46). However, the IOS is simple to use and effort- and respiratory muscle-independent, thus reducing the effects of premature airway closure (4), and thus could measure the small airway “quiet zone,” enabling respiratory system distensibility and identification of nonuniformities in airflow distribution (47). These advantages of the IOS with regard to the lung physiology may have resulted in the better differentiation of airway hyperreactivity in these young children using the IOS compared with the spirometry. Hence, we speculate that the oscillometric BDR may be a useful supplement to spirometric BDR in the diagnosis of asthma and add more information about a clinical profile of asthma in young children with small airway hyperresponsiveness.

Strengths and limitations

This study compared various lung function measures of a large cohort of children who had various reasons for undergoing BDR tests, and therefore examined children in a real clinical setting. In addition, because the two tests characterize different aspects of lung mechanics, we did not simply assess which one is better than the other. Instead, we focused on the clinical relevance of airway hyperresponsiveness as measured by the two tests. We identified the clinical characteristics of subjects who had different spirometric and oscillometric BDR results. However, this study did not compare asthma patients with controls; rather, we included subjects with asthma and

diagnoses other than asthma; these different diagnoses may have affected the concordance of the oscillometric and spirometric BDR results. Therefore, our findings may not be applicable for subjects with asthma. Furthermore, we did not determine whether IOS parameters are more sensitive than FEV₁ from spirometry in the evaluation of asthma (13,21,48). There is a controversy regarding cutoff values for determining bronchial hyperresponsiveness using FEV₁ from spirometry (49) and Rrs₅ from IOS (−40%, (50) 29% (40), 20–25% (14), and 29% (11)). Data on airway hyperresponsiveness from the IOS is heteroscedastic, and reference equations differ among institutions; therefore, we generalized data using relative and absolute changes, a possible limitation of the current study (16,39).

Conclusions

Baseline lung function values strongly influenced spirometric and oscillometric BDR results. Use of IOS BDR data enabled us to differentiate children with small airway hyperresponsiveness who were not identified using spirometric BDR. However, the agreement between the spirometric and oscillometric BDR results was low. Subjects with small airway hyperresponsiveness were more likely to have positive values of parameters frequently used in the diagnosis of asthma. We determined that the oscillometric BDR test to detect small airway hyperresponsiveness may add more information to the spirometric BDR test regarding a clinical profile of subjects with asthma. Therefore, IOS can be a useful supplement to spirometry, particularly, in children with small airway hyperresponsiveness who may not be identified using spirometry.

Declaration of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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