Research Article

Lung Function Assessment With Impulse Oscillometry (IOS) in Adolescents with Severe Asthma During the Asymptomatic Period: A Preliminary Study

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Abstract

Introduction: Impulse oscillometry (IOS), a non-invasive forced oscillation technique for assessing lung functions during quiet breathing, is an alternative method to the gold standard spirometry. Normal spirometry during asymptomatic periods is a major obstacle to diagnosing asthma.

Objectives: To assess lung functions of adolescents with severe asthma from the municipal council area of Anuradhapura, Sri Lanka using IOS during their asymptomatic period.

Methodology: A preliminary study was conducted in a convenient sample of 15 adolescents aged 13-14 years with severe asthma detected using the validated International Study of Asthma and Allergy in Childhood (ISAAC) questionnaire during the asymptomatic period. IOS was conducted per European Respiratory Society and American Thoracic Society guidelines with standard calibration, adequate training, and height and weight measurement. The best values of reactance (X) and resistance (R) were calculated at frequencies 5 to 20 Hz (R5, R10, R20, and X5). The standard cut-off of 150% of the predicted value was considered. Bronchodilator administration was conducted with a short-acting inhaled bronchodilator (200 µg MDI salbutamol with spacer) repeating IOS 15 minutes later.

Results: The study sample consisted of 7 boys and 8 girls. Most participants (n=13, 86.67%) had normal IOS results. Significantly increased total (R5) and mid-airway (R10) resistance, with normal large airway (R20) resistance, indicative of significant peripheral airway resistance (R5-20), was detected in one participant. Another participant had significantly increased resonance frequency with normal R and X indicative of either obstructive or restrictive disease.

Conclusion: Evidence suggestive of airway obstruction was found in 2(13.3%) participants highlighting the utility of IOS in diagnosing asthma even in the asymptomatic period.

Keywords: adolescents, lung functions, impulse oscillometry, asthma

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Introduction

Asthma is a heterogeneous disease characterised by chronic airway inflammation and airflow obstruction. It is defined by a history of respiratory symptoms, such as wheezing, shortness of breath, chest tightness, and cough, that vary over time and in intensity, together with variable expiratory airflow limitation [1]. According to the Global Burden of Disease estimates more than 260 million individuals worldwide are suffering from current asthma (defined as asthma with wheezing during the previous 12 months) in 2019, with a significant number of disabilities and early deaths across several low-and-middle-income countries [2]. According to the studies based on the International Study of Asthma and Allergy in Childhood (ISAAC) questionnaire, the mean worldwide symptom prevalence of current wheeze in the last 12 months has changed slightly from 13.2% to 13.7% in adolescents with a mean increase of 0.06% per year from 2017 to 2020 [3]. In 2012, the prevalence of current symptoms of asthma in the males and females of 13–14-year age group in Asia was 8.9% and 8.6%, respectively [4].

According to the annual health statistics published by the Ministry of Health Sri Lanka for 2021, 62,635 asthma cases and 292 deaths have been reported [5]. A school-based study among early adolescents aged 12-14 years in Gampaha district, Western province of Sri Lanka reported prevalence rates of ever wheezing, current wheezing, current asthma, and physician-diagnosed asthma as 19.4%, 16.7%, 10.7%, and 14.5%, respectively [6]. Alarmingly, the annual health statistics published by the Ministry of Health Sri Lanka for 2021, report that the case fatality rate was 0.34 per 100 cases in the Anuradhapura district [5].

Asthma impacts the quality of life at all ages and this effect is prominent in children and adolescents [2]. While asthma incidence is reported highest before age 5, prevalence and disability-adjusted life years peak before 14 years [7]. Furthermore, adolescence is decisive for the gender-dependent development of lung function [8]. Adolescence marks the highest clinical remission (35%) of asthma (no symptoms or asthma medication for at least 1 year) [9]. Therefore, it is vital to reassess the lung functions of adolescents even if they were diagnosed as children. Normal spirometry results during the asymptomatic period in some children and adolescents are a significant hurdle in diagnosing asthma with spirometry which is the gold-standard test [10].

Impulse oscillometry (IOS) is a non-invasive lung function test that identifies airway mechanic measurements based on the forced oscillation technique (FOT) [11]. FOT assesses the airways by delivering external, sinusoidal, single-frequency sound waves in the range of 3 Hz to 35 Hz into the airways superimposing them on tidal volume breathing [12]. The IOS is an upgraded version of FOT applying multiple square-wave oscillations simultaneously using a computer-based loudspeaker reducing the time required for testing [13]. Sound waves travel through the tracheobronchial tree and measure the pulmonary impedance that includes resistance (R) and reactance (X) in a range of frequencies [14]. At the 5 Hz frequency, sound waves travel through large, intermediate, and small peripheral airways, therefore, it is used to ascertain total airway resistance. As the higher frequency waves travel only a short distance, R20 represents the resistance of the large airways. So, by subtracting the resistance of large airways from the total airways (R5-20) the resistance of peripheral airways is calculated [15]. Reactance (X) consists of inertance and capacitance which are the inert force of the moving air column, and compliance of the lungs respectively. Therefore, reactance is a measure of the distensibility of the airways [16].

Performing IOS is relatively more convenient compared to the gold standard test spirometry as it requires only minimal cooperation from the participants [17]. Therefore, currently, IOS is being explored as an alternative convenient and feasible lung function testing method [18]. IOS findings are independent of age, height, weight or gender in people over 13 years of age [18]. Furthermore, it is ideal for the assessment of airways in children and young adolescents who are incapable of performing complicated respiratory manoeuvres precisely following the instructions of the spirometry technician [19]. As IOS involves minimal patient cooperation, it also can be performed in participants who are contraindicated for forced expiratory manoeuvres [20].

This study aimed to diagnose asthma using IOS in adolescents categorised as severe asthmatics using the epidemiological tool, ISAAC questionnaire, during their asymptomatic period. Severe asthma was defined in the ISAAC study as having more than 12 attacks of wheezing, sleep being disturbed one or more nights per week, and/or wheezing ever being severe enough to limit the speech to only one or two words at a time between breaths in the past 12 months [21]. An asymptomatic period was purposely selected because most children and adolescents with asthma present for specialist consultation and the resultant lung function assessment occurs during an asymptomatic period more commonly than during acute exacerbations when most children and adolescents present to emergency care services of both public and private sector in the local context. Therefore, it is critical to assess the capacity of IOS to detect small airway obstruction during the symptomatic period which would greatly enhance objective diagnosis of asthma.

Methodology

Study setting and design

A preliminary study was conducted in Government schools of the municipal council area of Anuradhapura, Sri Lanka.

Study population and sample

A simple random convenient sample of 15 adolescents attending government schools in the municipal council area, Anuradhapura, Sri Lanka and identified to have severe asthma in a previously published analytical cross-sectional study were selected [22]. In the current study, adolescents with severe asthma who were asymptomatic for a minimum of one month duration were selected irrespective of current treatment.

Study tools

The ISAAC questionnaire, which is widely used in epidemiological studies in many countries including Sri Lanka to assess the prevalence and factors associated with asthma, allergic rhinitis, and eczema, was used in the current study to identify adolescents with severe asthma [21]. IOS was performed in adolescents who were categorised as severe asthmatics and were asymptomatic for at least one month at the time of testing.

Procedure of performing IOS

Participants were instructed to withhold short-acting bronchodilators for 4 hours and long-acting bronchodilators for 24 hours, before performing IOS as per standard guidelines [23]. Before performing IOS, the height, and weight of the study participants were measured using a portable stadiometer (Seca 213) and a digital bathroom scale (Seca Clara 803) according to standard techniques. IOS was conducted using the Vyntus IOS® with MicroGrad® bacterial/viral filter. Calibration of the equipment was performed according to the manufacturer's instructions on site.

To perform IOS, first, the adolescent was requested to sit or stand wearing a nasal clip. Then they were instructed to seal their lips around the mouthpiece without obstructing the airflow with the tongue and without biting the mouthpiece. IOS was performed while the adolescent continued to take normal tidal volume breaths with the parent supporting the cheeks of the adolescent. The pulmonary impedance was recorded as R (energy required to propagate the pressure wave through the airways) and X (a measure of the viscoelastic properties of the respiratory system) [11]. A 30-second interval of testing was used and tidal volume breaths with no evidence of coughing, swallowing, vocalization, or breath-holding were considered acceptable trials [11,23,24]. IOS was repeated 15 minutes after the administration of a short-acting inhaled bronchodilator (200 µg of metered-dose inhaler salbutamol with a spacer device).

Statistical analysis and interpretation of IOS results

The X and R values of three acceptable trials were used to calculate the reported mean R5, R10, R20, and X5 values. R5 is the total airway resistance which includes both central and peripheral airways. R10 is considered the transition point between central and peripheral airways and R20 measures the central airway resistance [25]. In addition, the area of reactance (AX) which represents the summation of reactance values below the resonant frequency (Fres), was measured [11]. Fres is the frequency at which the X is zero where the elastic and inertial properties of airways cancel out and, therefore, the reactance is zero. Currently, there are no globally accepted cutoff values for Fres and national standards or study-specific thresholds are used [26]. Therefore, the commonly considered 150% cutoff for Fres was used. Criteria to categorize the airway status are as follows. The predicted values for R and X were automatically calculated by the Vyntus® IOS device based on gender and anthropometric measurements (height) based on the existing reference formula and the standard cut-off of 150% of the predicted value was considered [27]. R5 is less than 150% of predicted in the normal airway and in restrictive airway diseases which are differentiated by X5 being more than -0.15 kPa.s.L-1 (closer to zero) in the normal airway and X5 being less than -0.15 kPa.s.L-1 (more negative) in restrictive airway diseases. In obstructive airway diseases, R5 is equal to or more than 150% predicted and X5 is more negative than -0.15 kPa.s.L-1 [24]. The widely used small airway index (R5-R20) of more than 0.07 kPa.s.L-1 for peripheral airway obstruction was used in the current study [28].

Ethical considerations

Ethical approval was obtained from the Ethics Review Committee of Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka (ERC/2023/03).

Informed written consent was obtained from the parent or guardian and written assent was obtained from the adolescent before recruiting to the study.

Results

The study sample consisted of 8 males and 7 females who were 13-14 years old. Table 1 summarizes some sociodemographic and anthropometric data. The body-mass index ranged between 12 to 23 kg/m2. The selected participants had no acute exacerbations of asthma during the last one-month period and before performing IOS, routine treatments were withheld according to the standard guidelines [23]. The lung function results as revealed by IOS are presented in Table 2.

Table 1: Anthropometric and demographic details of study participants (n=15)

Participant	Age (years)	Sex	Height (cm)	Weight (kg)	BMI* (kg/m^2)	Residential area	Urban/ rural
1	13	Female	160	55	21	Anuradhapura	Urban
2	13	Female	146	26	12	Thambuttegama	Rural
3	13	Male	158	33	13	Rambawa	Rural
4	13	Female	164	63	23	Rambawa	Rural
5	13	Male	153	29	12	Dahayyagama	Urban
6	13	Female	162	49	19	Thambuttegama	Rural
7	13	Female	151	39	17	Thalawa	Rural
8	14	Male	169	42	15	Saliyapura	Rural
9	13	Female	145	37	18	Anuradhapura	Urban
10	13	Female	143	38	19	Anuradhapura	Urban
11	14	Male	163	48	18	Dahayyagama	Urban
12	13	Male	157	37	15	Thisawewa	Urban
13	13	Male	149	51	23	Kalaoya	Rural
14	13	Male	161	45	17	Anuradhapura	Urban
15	13	Male	157	37	15	Thalawa	Rural

*BMI: body-mass-index

Table 2: Impulse oscillometry results of study participants (n=15)

Research participant		Resistance (*KPa/(L/s)*) 5 Hz	10 Hz	20 Hz	Frequency dependence R5-20%	Reactance at 5 Hz	Resonance frequency (L/s)	Ventilatory time	Airway status
1	**Predicted**	0.54	0.43	0.40		-0.15	14.02	0.52	Normal
	Pre	0.47	0.36	0.35	25.88	-0.12	16.32	1.07	
	%Predicted	93.2	83.9	86.9		80	116	207.7	
	Post	0.38	0.32	0.32		-0.14	13.19	0.82	
	%Predicted	76.5	76.2	80.7		94	94	159.3	
	%Change	-19.15	-11.11	-8.57		16.67	-19.18	-23.36	
2	**Predicted**	0.48	0.41	0.39		-0.14	12.65	0.44	Peripheral airway obstruction
	Pre	0.78	0.57	0.40	49.09	-0.16	1.76	0.98	
	%Predicted	163.7	140.3	100.8		112	14	223.7	
	Post	0.75	0.55	0.37	50.03	-0.25	22.77	1.17	
	%Predicted	156.2	135.7	94.6		173	180	269	
	%Change	-3.85	-3.51	-7.50	1.91	56.26	1193.75	19.39	
3	**Predicted**	0.45	0.39	0.35		-0.14	14.22	0.51	Obstructive or restrictive airway disease
	Pre	0.48	0.40	0.37	24.02	-0.09	23.85	1.04	
	%Predicted	106.9	104.1	103.7		66	168	206.6	
	Post	0.5	0.37	0.25	48.37	-0.11	17.55	0.95	
	%Predicted	109.8	96.4	71.7		78	123	189	
	%Change	4.17	-7.50	-32.43	101.37	22.22	-26.42	-8.65	

4	**Predicted**	0.51	0.43	0.4		-0.15	14.36	0.54	Normal
	Pre	0.67	0.5	0.47	29.81	-0.08	3.24	1.94	
	%Predicted	133.3	116.8	118.6		52	23	358.6	
	Post	0.55	0.45	0.32	42.38	-0.04	3.18	1.7	
	%Predicted	108.9	104.7	79.7		25	22	313.1	
	%Change	-17.91	-10	-31.91	-42.17	-50	-1.85	12.37	
5	**Predicted**	0.48	0.4	0.37		-0.15	14.68		Normal
	Pre	0.61	0.49	0.36	41.32	-0.15	22.06	0.67	
	%Predicted	127.9	121.7	97.2		97	150	141.5	
	Post	0.51	0.46	0.36	29.25	-0.19	19.91	0.74	
	%Predicted	107.5	113.5	98.7		123	138	156.4	
	%Change	-16.39	-6.12	0	-29.21	26.67	-9.75	10.45	
6	**Predicted**	0.46	0.39	0.38		-0.13	12.53	0.53	Normal
	Pre	0.51	0.41	0.37	27.5	-0.09	20.62	1.48	
	%Predicted	113.1	105.2	99.2		72	165	279.1	
	Post	0.45	0.38	0.32	28.55	-0.12	19.10	1.27	
	%Predicted	99.5	98.7	86.3		98	152	239.4	
	%Change	-11.76	-7.32	-13.51	3.82	33.33	-7.37	-14.19	
7	**Predicted**	0.50	0.42	0.4		-0.15	13.58	0.46	Normal
	Pre	0.47	0.37	0.40	14.55	-0.16	14.16	1.71	
	%Predicted	93.2	88.1	98.8		105.2	104.3	367.6	
	Post	0.36	0.34	0.36	2.50	-0.14	11.59	1.29	
	%Predicted	72.5	80.1	89.3		88.8	85.4	287.2	
	%Change	-23.40	8.11	-10	-82.82	-12.5	-18.15	-24.56	
8	**Predicted**	0.42	0.35	0.33		-0.12	13.21	0.57	Normal
	Pre	0.40	0.36	-0.34	14.34	-0.10	14.94	1.87	
	%Predicted	98.9	101.9	104.1		81	113	326.00	
	Post	0.35	0.32	0.32	9.40	-0.10	11.74	1.57	
	%Predicted	86.3	89.6	96.00		85	89	274.8	
	%Change	-12.5	-11.11	-194.12	-34.45	0	-21.42	-16.04	
9	**Predicted**	0.54	0.46	0.42		-0.17	14.73	0.43	Normal
	Pre	0.66	0.42	0.27	59.36	-0.20	8.89	1.21	
	%Predicted	121.5	92.2	63		117	60	282.3	
	Post	0.56	0.34	0.25	55.84	-0.13	10.08	1.47	
	%Predicted	103.7	74.8	58.3		72	68	340.9	
	%Change	-15.15	-19.05	-7.41	-5.93	-35	13.39	21.49	
10	**Predicted**	0.56	0.47	0.43		-0.19	15.39	0.42	Normal
	Pre	0.66	0.49	0.48	27.84	-0.08	3.07	1.36	
	%Predicted	117.7	103	109.9		44	20	323.9	
	Post	0.63	0.55	0.54	14.58	-0.13	15.84	1.06	
	%Predicted	112.1	117.2	123.8		69	103	251.9	
	%Change	-4.55	12.24	12.5	-24.63	62.5	415.96	-22.06	
11	**Predicted**	0.42	0.36	0.34		-0.12	13.33	0.54	Normal
	Pre	0.47	0.44	0.36	23.57	-0.04	18.41	1.85	
	%Predicted	112.7	122.2	107.5		33	138	345	
	Post	0.48	0.44	0.37	22.35	-0.06	19.50	1.95	
	%Predicted	114.9	122.4	110.9		47	146	364.5	
	%Change	2.13	0	2.78	-5.18	50	5.92	5.41	
12	**Predicted**	0.49	0.42	0.40		-0.16	13.88	0.43	Normal
	Pre	0.57	0.38	0.28	50.51	-0.18	14.22	1.18	
	%Predicted	115.5	90.9	70.4		114	102	274.5	

	Post	0.50	0.37	0.29	42.78	-0.13	19.93	1.36	
	%Predicted	103.0	89.7	72.7		83	144	315.9	
	%Change	-12.28	-2.63	3.57	-15.30	-27.78	40.15	15.25	
13	**Predicted**	0.57	0.48	0.42		-0.19	15.93	0.45	Normal
	Pre	0.60	0.42	0.30	50.78	-0.21	18.99	1.57	
	%Predicted	104.7	87	70.8		115	119	345.8	
	Post	0.62	0.41	0.31	50.11	-0.20	17.57	1.25	
	%Predicted	107.4	86.4	73.7		110	110	276.4	
	%Change	3.33	-2.38	3.33	-1.32	-4.76	-7.48	-20.38	
14	**Predicted**	0.47	0.4	0.36		-0.14	14.28	0.52	Normal
	Pre	0.54	0.4	0.36	32.28	-0.12	14.96	1.92	
	%Predicted	113.6	100.9	99.7		83	105	367.5	
	Post	0.47	0.38	0.36	22.08	-0.14	15.66	1.49	
	%Predicted	99.6	94.9	100		96	110	285.00	
	%Change	-12.96	-5	0	-31.60	16.67	4.68	-22.40	
15	**Predicted**	0.47	0.40	0.36		-0.15	14.48	0.50	Normal
	Pre	0.46	0.37	0.25	36.96	-0.24	19.51	1.42	
	%Predicted	98	92	70		161	135	284	
	Post	0.53	0.42	0.27	40.13	-0.17	19.64	1.44	
	%Predicted	113	104	74		116	136	101	
	%Change	15.22	13.51	8	-8.58	-29.17	0.67	1.41	

%Predicted: percentage predicted, Pre: pre-bronchodilator administration, Post: post-bronchodilator administration, %Change: (Post-Pre)/Pre as a percentage NR: not recorded

Thirteen participants had normal R5, R5-20 and X5. Participant 2 had increased R5 and R10 with normal R20 characteristic of high peripheral airway resistance (R5-20). The X5 was normal. His overall IOS results suggested a peripheral airway obstruction. However, the participant did not exhibit significant bronchodilator reversibility (Figure 1). Participant 11 showed increased R5 and R5-20 following bronchodilator administration albeit at non-significant levels.

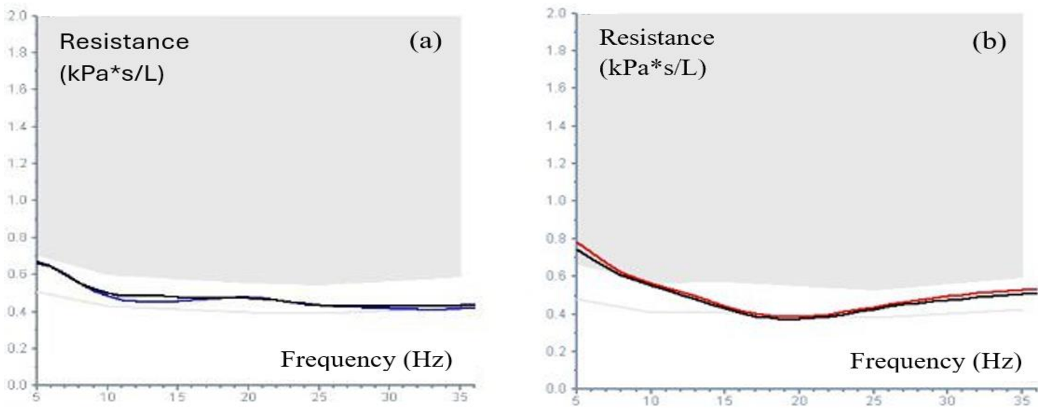

Figure 1: Impulse oscillometry resistance graphs of (a) participant 01 showing normal resistance and (b) participant 2 showing increased airway resistance in lower frequencies characteristic of peripheral airway obstruction. The red and black lines show pre- and post-bronchodilator impulse oscillometry respectively. The grey line is the resistance predicted for age, sex, and height. The grey-shaded area highlights the resistance exceeding the cutoff of 150% of the predicted value.

An increased resonance frequency, which is seen in both obstructive and restrictive airway diseases, was detected in participant 03 (Figure 2). However, participant 03 had normal resistance and reactance. Therefore, although participant 03 demonstrated evidence of having an airway disease, which is most likely to be asthma based on past medical history, IOS results are not diagnostic of asthma.

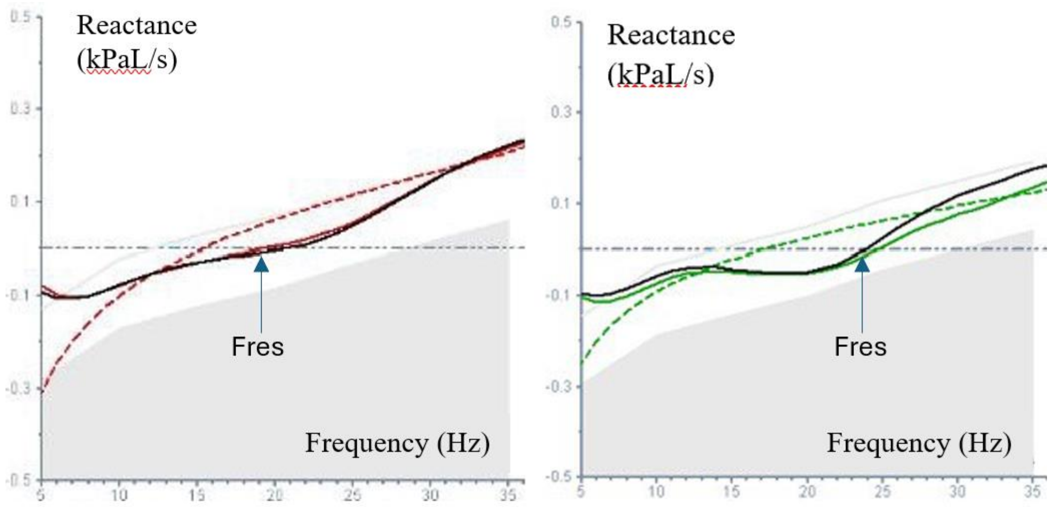

Figure 2: Impulse oscillometry reactance graphs of (a) participant 6 and (b) participant 3 show normal and increased resonance frequency (Fres, arrow), respectively. The solid green and red lines represent pre-bronchodilator reactance, while the solid black line represents post-bronchodilator reactance. The dotted red and green lines indicate the predicted (reference) reactance curves for the participant. The shaded area shows the reactance level below the 150% cutoff of the predicted value.

Discussion

This preliminary study conducted to assess lung functions using IOS in participants diagnosed with severe asthma and in asymptomatic period provides the first IOS results in Sri Lankan adolescents. We assessed the lung functions of 15 adolescents aged 13-14 years and schooling in the municipal council area of Anuradhapura, Sri Lanka. Participants in the asymptomatic period were purposely selected to test if IOS could be used during the asymptomatic period to detect abnormal airways as it would vastly improve the early detection of asthma. In the current study, only 2 participants (13.3%) were detected to have evidence of airway obstruction during their asymptomatic period.

One of them had evidence of peripheral airway obstruction (R5-20) with increased total (R5) and normal large airway resistance (R20). However, significant bronchodilator reversibility was not observed. The most alarming reason could be early and/or mild airway remodelling. Current evidence has shown airway remodelling can occur even in preschool children [29]. Also, residual inflammation without bronchial hyperresponsiveness, which occurs in the presence of underlying subclinical airway inflammation without accompanying smooth muscle constriction, would be unresponsive to bronchodilators because the root cause of impaired lung functions is not addressed through bronchodilator administration. This reduced bronchodilator response is even considered a hallmark of non-type 2 asthma and severe asthma exacerbations [30]. However, retesting on a different day to counter the variable nature of asthma and further investigations including assessing the atopic status with allergen sensitivity testing and other risk factors including active or passive smoking is essential before drawing conclusions. An increased resonance frequency was detected in another participant which is suggestive of either obstructive or restrictive airway disease. However, the resistance and reactance were normal. Therefore, evidence of some airway disease was demonstrated but it is not diagnostic of asthma. Normal IOS parameters during asymptomatic periods in adolescents with a history of asthma likely reflect well-controlled or currently quiescent disease [31]. However, due to the intermittent and variable nature of asthma, normal values do not exclude underlying airway hyperreactivity or future exacerbation risk [32,33].

The current study reports that 2 participants among 15 were detected to have evidence of airway obstruction despite being symptom-free. This may seem like a low diagnosis rate. However, considering these participants were in the asymptomatic stage, characteristic variable airflow limitation of asthma, lack of bronchoconstriction in between exacerbations in some asthmatics, and the general tendency of asthmatics to have normal lung functions with spirometry during the asymptomatic period, these results are encouraging and should be further explored in a large-scale study with adequate sample size (34). Similar results were observed in a previous study conducted on preschool children of the same region further providing evidence that IOS should be utilised in children and adolescents who tend to experience more difficulties with spirometry compared to adults [35]. Therefore, these results highlight the utility of IOS in detecting abnormal airway functions even in asymptomatic adolescents. Furthermore, repeat IOS and spirometry during symptomatic episodes in children and adolescents who show normal lung function during asymptomatic periods is recommended as per current international recommendations [33]. This is especially relevant in cases where clinical suspicion of asthma is high, as there are no definitive diagnostic biomarkers for asthma outside of symptomatic periods, and lung function variability is a hallmark of the disease [36].

Studies conducted to assess lung function among adolescents with both spirometry and IOS have shown a correlation between spirometry results and IOS results. In a study conducted with participants with previous physician-diagnosed asthma but normal spirometry results, IOS-defined small airway dysfunction and spirometry-defined small airway dysfunction (according to FEF 25-75% less than 65%) were assessed in the same participants. IOS-defined small airway dysfunction was found in 54.1% of the cohort and only 10% of the cohort had spirometry-defined small airway dysfunction. Also, participants with IOS-defined small airway dysfunction showed less well-controlled asthma and higher mean inhaled corticosteroid dosage use compared with participants without small airway dysfunction [37]. This highlights the utility of IOS as a lung function testing method [38]. Another study conducted with participants over the age of 13 years with asthma at baseline performed spirometry and IOS following short-acting bronchodilator administration, and at follow-up after at least three months of inhaled corticosteroid treatment [39]. The IOS showed improvement in airway function both initially, following short-acting bronchodilator introduction, and later after initiation of long-term inhaled corticosteroid treatment, even when the spirometry did not reveal improvement. So, this may provide a better measure for identifying asthma, diagnosis and follow-up. A prospective study including children with lung function assessment with IOS at 4, 5, and 6 ages and spirometry at 5, 6, 7, and 8 years showed that respiratory resistance at 5 Hz at the age of 4 years was also associated with decreased lung function from ages 5 to 8 years [40]. Recommendations for using IOS to diagnose asthma include conducting IOS before spirometry. For adolescents, building rapport and providing tailored instructions are vital. For this, training needs to be provided to technicians. It is advisable to conduct the testing in a calm, non-disruptive environment.

One participant showed a significant increase in airway resistance following bronchodilator administration, which could be attributed to paradoxical bronchoconstriction. It is a condition which occurs following administration of beta-2 agonists in patients with obstructive airway, where unusual worsening of lung functions occur instead of the expected improvement [41].

A major limitation of the current study is the limited sample size - chosen for convenience in this preliminary study - which might not fully represent the variable demographics of all asthmatic patients. Results can also be affected by the participant's level of cooperation and the clarity of the instructions given which should be further evaluated in a qualitative study designed to explore the problems faced during IOS by technicians and adolescents. The normal IOS results do not necessarily mean that the participant does not have obstructive airway disease: Repeat IOS when the participant is symptomatic is the next step in lung function evaluation.

Conclusion

This preliminary study shows that IOS can be useful in detecting airway dysfunction even in asthmatics who are not acutely symptomatic. However, further evidence with a larger sample size and longitudinal follow-up is required to generalize the findings to the population.

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