Research article

Lung function assessment in preschool children with symptoms of asthma: A preliminary study

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Background
Asthma causes a significant disease burden in children and it is objectively diagnosed by demonstration of reversible airway obstruction. However, objective diagnosis of airway obstruction in preschool children with asthma symptoms is not frequently practised in Sri Lanka.

Methodology
This study was a descriptive cross-sectional preliminary study conducted in a convenience sample of 11 consecutive children aged 3-6 years presenting with symptoms of asthma. Asthma Control Test (ACT) was used to assess symptom control. Lung function assessment was carried out using spirometry and impulse oscillometry (IOS) according to European Respiratory Society and American Thoracic Society guidelines. Airway obstruction cut-off was considered as the forced expiratory volume in the first second (FEV_1): forced vital capacity (FVC) ratio less than 0.9.

Results
The study sample consisted of 4 boys and 7 girls. Nine participants had good control of asthma symptoms (ACT>19). Only three participants performed spirometry in an acceptable and reproducible manner and two of them demonstrated evidence of airway obstruction. FVC less than 0.8 was noted in two participants probably attributable to poor effort (pseudo-restriction). Significant bronchodilator reversibility was not demonstrable in any patient, and two participants had reduced FEV_1:FVC ratio following administration of beta-2-agonists probably due to paradoxical bronchoconstriction or improvement of FVC.

IOS assessment was completed successfully by seven children. Increased R5-20 was detected in 3 participants and increased resonance frequency in another two children, suggesting probable peripheral airway involvement.

Conclusion
Airway obstruction in preschool children could be assessed using spirometry and IOS. IOS is more feasible in preschool children.

Keywords: Spirometry, Impulse oscillometry, Lung function assessment, Asthma, Preschool children

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Introduction

Asthma is a common chronic disease affecting children and a leading cause of morbidity in children [1]. The epidemiology of asthma symptoms in preschool children has been studied in the urban [2] and rural Sri Lanka with a reported prevalence of 7.2% (95%CI 5.7-8.9) in the Anuradhapura district [3]. Phase 3 of the International Study of Asthma and Allergy in Childhood (ISAAC) study showed that 16.5% of 6-7-year-old children classified as current wheezers with severe asthma symptoms have never been previously diagnosed with asthma [4] and the prevalence of parent-reported wheezing is reported to be higher than general practitioner-diagnosed asthma in 3-5-year-olds [5]. Therefore, an objective diagnosis of asthma is important in symptomatic children compared to the current practice of clinical history and examination-based diagnosis.

The American Thoracic Society/European Respiratory Society (ATS/ERS) and Global Initiative for Asthma (GINA) guidelines recommend spirometry with bronchodilator reversibility for asthma diagnosis [6]. However, performing reliable spirometry in preschool children is challenging. Furthermore, technical standards, analysis and interpretation of spirometry data should take into consideration the anatomical and physiological status of the child, which vary with age, sex and anthropometry, as recommended by the ATS/ERS Task Force [7]. However, the practical application of spirometry in young children is limited [8] due to lack of access, difficulty in performing the complicated manoeuvres, and difficulty in the interpretation of results [9]. Impulse oscillometry (IOS) is an alternative test requiring minimal cooperation compared to spirometry. IOS uses a computer-based loudspeaker to apply multiple square-wave oscillations into the airways superimposed on tidal volume breathing to measure pulmonary impedance in a range of frequencies. Impedance includes airway resistance (R) (energy required to propagate the pressure wave through the airways) and reactance (X) (a measure of the viscoelastic properties of the respiratory system). The penetration of these external sound waves depends on the frequency: the lower the frequency, the longer the distance travelled along the tracheobronchial tree. The authors have previously published a review on the advantages, disadvantages and feasibility of lung function techniques including spirometry and oscillometry [10].

The current study was conducted in a sample of preschool children aged 3-6 years who presented with wheezing to the paediatric clinic of the professorial unit of the Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka (FMAS, RUSL). The objective was to assess lung functions and their feasibility in preschool children with symptoms of asthma using spirometry and IOS and address common issues in objectively diagnosing preschool children with wheezing.

Methodology

Design

This was a preliminary study conducted in a convenient sample of pre-schoolers.

Study sample

Eleven children aged 3-6 years with wheezing were recruited from the paediatric clinic of the professorial unit of the FMAS, RUSL from January to May 2022.

Procedure

Ethical approval was obtained from the Ethics Review Committee of FMAS, RUSL (ERC 2021/75). Initially, informed written consent was obtained.

Study tools

A self-administered questionnaire on the demographic details, housing conditions, exposure to allergens, past and current medical history and drug history was answered by parents and guardians at the paediatric clinics. The asthma control test was administered over the phone with verbal consent to assess asthma control [11]. The standard cut-off for poorly or partially controlled asthma of 19 or fewer was used in this study [12].

Height and weight measurements were performed with a portable Stadiometer (Seca 213) and a digital bathroom scale (Seca Clara 803) using standard techniques and procedures. Vyntus IOS® with MicroGrad® bacterial/viral filters were used for lung function assessment. Lung function testing was performed by a medical doctor with lung function testing training according to ATS/ERS and GINA guidelines. During testing, the difficulties faced by the preschool children were also observed by the investigator.

All the lung function measurements were taken in the standing position. When performing IOS, nose clips were applied and children were asked to seal their lips around the mouthpiece of the IOS device without obstructing with the tongue. With the cheeks supported,

the children were instructed to take normal tidal volume breaths. Each trial was 30 seconds, and 3 acceptable (no evidence of coughing, swallowing, vocalization, or breath holding) trials were selected. The best values of reactance and resistance were obtained at frequencies ranging from 5 to 20 Hz. Predicted values for R and X were based on gender and anthropometric measurements (height) according to the equipment's default normal reference values. The standard cut-off of 150% of the predicted reference value was considered in IOS.

Since the children had no prior experience with spirometry, each child was individually instructed and guided during the manoeuvre. Each child was instructed to blow into a party favour, to explain to them the three critical manoeuvres take a deep inspiratory breath, "blow as fast as possible", and "for as long as possible" to facilitate understanding of the respiratory manoeuvres required for forced spirometry. Then the children were instructed to perform the respiratory manoeuvre without the mouthpiece to confirm that they had learnt the technique. Each child held a disposable tube in his/her mouth, in a manner to prevent leakage of air and wore a nasal clip to occlude the nose. The children performed the learnt manoeuvre in the standing position with monitoring of the flow volume curve on the computer screen during every attempt. A minimum of three spirometry attempts were recorded. Flow volume curves that demonstrated a rapid rise to the peak expiratory flow, a slow steady decline without evidence of glottis closure, cough or other artefacts and conformed to technical specifications specified by ERS/ATS guidelines were selected. Airway obstruction cut-off was considered as forced expiratory volume in the first second (FEV_1): forced vital capacity (FVC) ratio less than 0.9 [13].

Results

The study sample consisted of 4 boys and 7 girls aged 3-6 years. The mean body mass index was 14.6 kg m-2 (11.4-20.9). Participants 1,2 and 9 were on inhaled corticosteroids. All participants except 1, 2 and 8 were on inhaled reliever therapy. Only participant six had poorly controlled asthma. Spirometry and IOS results are presented in Tables 1 and 2, respectively. The research participants showed variable performance in repeated attempts, therefore, the best values of individual parameters from all the attempts are reported (7). Objective evidence of airway obstruction was detected with spirometry and IOS in 2 and 3 preschool children, respectively. Interestingly, none of the 3 participants (participants 6, 7 and 8) with objective evidence of airway obstruction had a diagnostic spirometry result. One of the two participants (participant 2) with evidence of airway obstruction in spirometry, had elevated Fres which is seen in both obstructive and restrictive airway diseases. The other participant that showed obstructive features in spirometry also had features of restrictive airway disease (mixed airway disease) warranting further investigation. Most participants performed spirometry only moderately satisfactorily with only 3 children having technically-satisfactory performances. This led to difficulty in meeting the spirometry criteria to diagnose airway obstruction. Comparatively, a better performance was observed during IOS testing with five children having technically satisfactory performances. The difficulties in conducting IOS and spirometry noted during testing are summarized in Table 3. During IOS testing, three participants had difficulty in breathing through the mouth with a nasal-clip on and two of them opened their mouth to breathe during testing. During spirometry testing, irritability, poor inspiratory effort and poor expiratory effort were noted in 2, 3 and 6 children, respectively. Participants 2 and 5 demonstrated poor inspiratory and expiratory efforts (Figure 1). Participants 7 and 8 had poor technique and, despite, younger age participant 6 showed better performance (Figure 2). The technique of participant 9 demonstrates limited compliance common in young children (Figure 2 f and 2g)

Discussion

This study is the first report of lung function assessment using IOS and spirometry in Sri Lankan preschool children. Airway obstruction was demonstratable using IOS and spirometry in three and two out of eleven children, respectively. None of the children had an evidence-based diagnosis of asthma, though some were managed as asthmatics and others were on inhaled corticosteroids. Some children were only on reliever therapy despite frequent and severe symptoms and poor asthma control. This highlights the need for an objective assessment of lung functions in preschool children with symptoms of asthma.

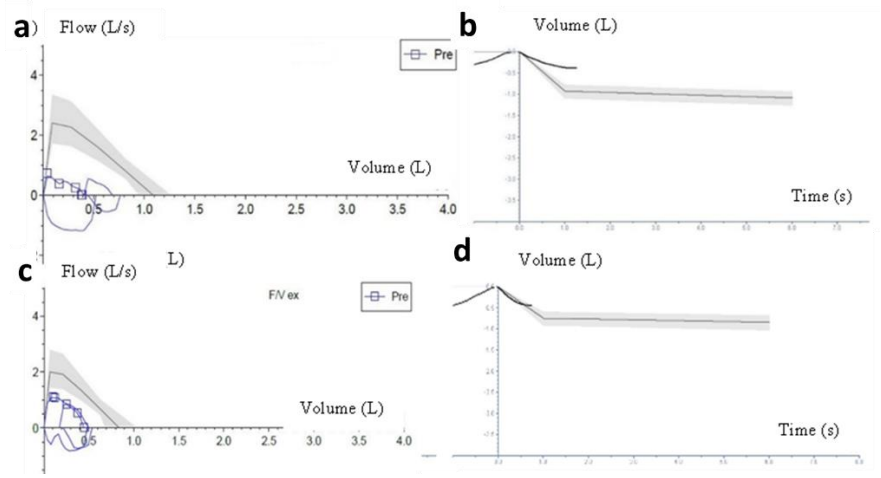

Figure 1: Prebronchodilator administration forced spirometry flow-volume loop (a) and volume-time graph (b) of participant 2 and participant 5 (c and d)

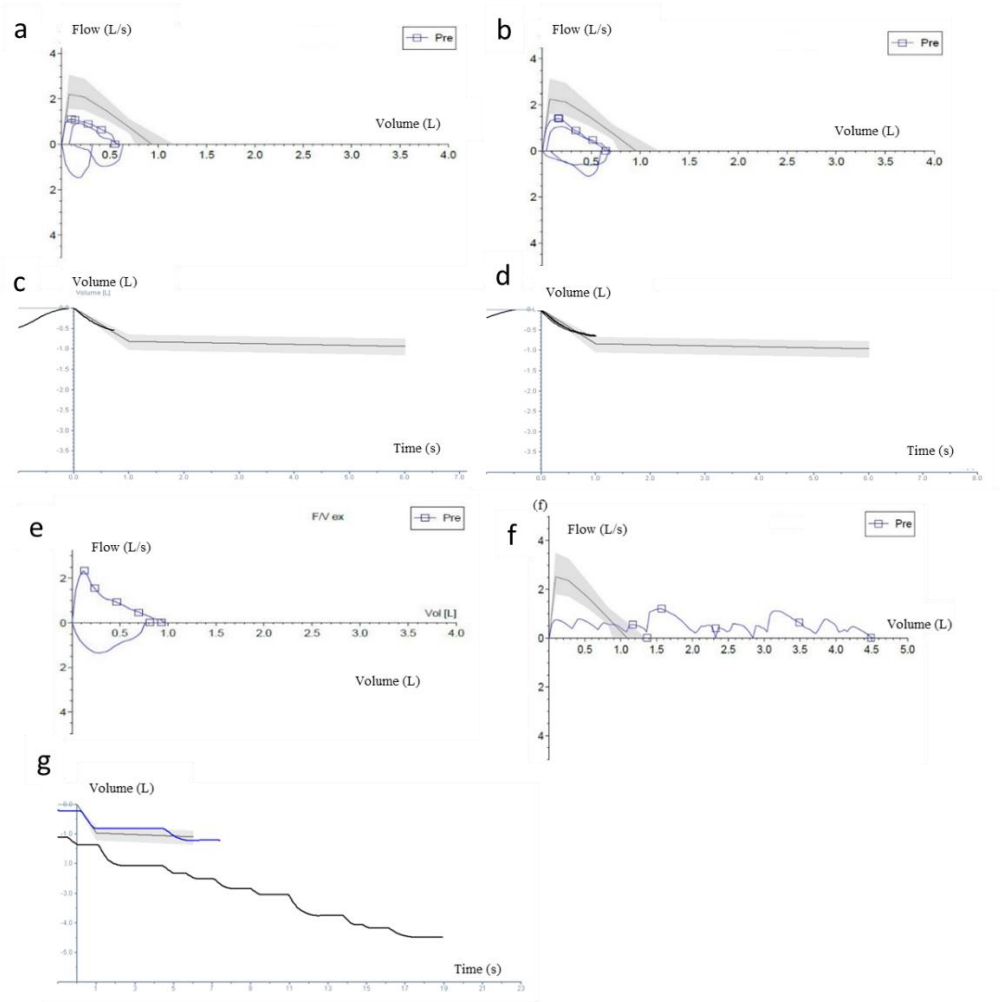

Figure 2: Prebronchodilator administration forced spirometry flow-volume loop *(a)* and volume-time graph (b) of participant 7, participant 8 (c and d), flow-volume loop of (e) of participant 6 and flow-volume loop of (f) and volume time graph (g) of participant 9.

Currently, there is sufficient evidence to support lung function testing in preschool children. A feasibility study conducted on 652 children aged 3-6 years from Norway showed that 408 children achieved three acceptable manoeuvres for spirometry and children with only two acceptable curves were younger, physically shorter and had a lower weight [16]. Therefore, current ATS/ERS and GINA guidelines recommend spirometry in preschool children for lung function assessment with acceptable changes compared to older children and adults. In this context, the current study provides first evidence that it is possible to obtain valid and repeatable lung function results in Sri Lankan preschool children.

The current study demonstrated that the measurement of airway resistance using IOS was a more sensitive test compared to spirometry. None of the three participants who had evidence of airway obstruction with IOS had evidence of obstructive airway disease with spirometry due to poor technique. In another participant with normal spirometry, IOS showed significantly elevated Fres and normal resistance, with a significant postbronchodilator reduction in resistance parameters as well as Fres and X5 indicative of probable peripheral airway obstruction. Current medical literature too describes that IOS correlates well with spirometry in preschool children [17] and that IOS is more feasible in assessing bronchodilator response, disease control and bronchoprovocation testing [18].

Pseudo-restriction of airways was observed in two participants. A pseudo-restrictive pattern is the demonstration of a reduced FVC with normal or high FEV_1:FVC, high residual volume and normal or high total lung capacity as opposed to a true restrictive pattern where the FVC, residual volume and total lung capacity is reduced [19]. Therefore, in suspected cases of pseudo-restriction, the total lung capacity should be assessed to demarcate true and pseudo-restriction [20].

Three participants showed significant increase in airway resistance following bronchodilator administration which could be attributed to paradoxical bronchoconstriction, where unusual worsening of lung functions occurs following beta-2 agonist administration in patients with obstructive airway disease instead of the expected improvement [21]. The prevalence of paradoxical bronchospasm in subjects aged 7-98 years was reported as 4.4% [22].

However, extensive studies on paradoxical bronchospasm are lacking in the medical literature.

The most difficult aspect in these children was obtaining a maximal forceful inspiration and expiration. Further explanations, especially through parent(s), additional demonstrations using party favours, on-screen incentives and repeated attempts markedly improved the performance. Some participants were on bronchodilators and/or inhaled corticosteroids and all but one participant had good asthma control which may have contributed to having normal lung function results. In such instances, serial lung function testing is recommended. Furthermore, the successful demonstration of obstructive airway disease in this preliminary study should be explored in future larger studies and clinicians should be encouraged to request lung function testing in children with symptoms of asthma.

Conclusion

Spirometry and IOS could be used to objectively detect airway obstruction in preschool children, though technical issues make IOS a more feasible test in this age group.

Table 1: IOS results of research participants (N=10)

Research participant		Resistance (*KPa/(L/s)*)			Frequency dependence R5-20%	Reactance at 5 Hz	Resonance frequency (L/s)	Ventilatory time	Interpretation
		5 Hz	10 Hz	20 Hz					
1	**Pre**	0.74	0.75	0.61	18.00	0.19	7.46	0.27	Normal
	%Predicted	87.06	101.35	93.85		-73.08	42.80	93.10	
2	**Pre**	1.12	1.01	0.87	22.16	-0.14	24.78	0.30	Elevated Fres
	%Predicted	116.67	117.44	112.99		0.45	142.82	125.00	
3	**Pre**	0.98	0.62	0.42	NR	-0.23	2.12	0.56	Normal
	%Predicted	106.52	76.54	57.53		79.31	12.38	215.38	
	Post	1.49	0.80	0.53	NR	-0.43	4.95	0.82	
	%Predicted	161.96	98.77	72.60		148.28	28.90	315.38	
	%Change	52.04	29.03	26.19		86.96	133.49	46.43	
4	**%Predicted**	128.24	122.67	112.86		117.86	206.57	270.37	Elevated Fres
	Post	0.87	0.72	0.69	31.59	-0.15	23.66	0.79	
	%Predicted	102.35	96.00	98.57		53.57	145.33	292.59	
	%Change	-20.18	-21.74	-12.66	-29.47	-54.55	-29.65	8.22	
5	**Pre**	1.00	0.66	0.42	58.68	-0.23	5.76	0.62	Normal
	%Predicted	108.70	81.48	102.44		79.31	33.63	238.46	
	Post	1.49	0.87	0.53	64.41	-0.43	4.95	0.95	
	%Predicted	161.96	107.41	129.27		148.28	28.90	365.38	
	%Change	49.00	31.82	26.19	9.76	86.96	-14.06	53.23	
6	**Pre**	1.77	1.54	1.08	49.68	0.64	6.50	0.42	Obstructive
	%Predicted	173.53	167.39	128.57		-193.9	37.51		
7	**Pre**	1.52	0.88	0.63	67.88	-0.61	21.55	0.29	Obstructive
	%Predicted	149.02	95.65	75.00		184.85	125.44	126.09	
8	**Pre**	1.61	1.38	1.12	42.30	0.64	7.39	0.37	Obstructive
	%Predicted	162.63	155.06	136.59		-200.0	43.52	160.87	
	Post	1.37	0.92	0.69	49.24	-0.21	24.48	1.00	
	%Predicted	138.38	103.37	84.15		65.63	144.17	434.78	
	%Change	-14.91	-33.33	-38.39	16.41	-132.8	231.26	170.27	
9*	Refused to perform IOS								
10	**Pre**	0.87	0.62	0.55	40.61	-0.21	23.91	0.66	Elevated Fres
	%Predicted	102.35	82.67	80.88		77.78	144.91	244.44	
	Post	1.11	0.85	0.68	38.76	-0.19	4.35	0.70	
	%Predicted	130.59	113.33	100.00		70.37	26.36	259.26	
	%Change	27.59	37.10	23.64	-4.56	-9.52	-81.81	6.06	
11	**%Predicted**	126.85	94.90	82.02		74.29	27.40	0.00	Normal
	Post	1.36	0.98	0.89	51.98	-0.35	17.52	0.55	
	%Predicted	125.93	100.00	100.00		100.00	100.00	250.00	
	%Change	-0.73	5.38	21.92	-8.24	34.62	265.00		

%Predicted: percentage predicted, Pre: pre-bronchodilator administration, Post: post-bronchodilator administration, Fres: resonance frequency, NR: not recorded

Table 2: Spirometry results of research participants (N=10)

Participant		SVC (L)	FVC (L)	FEV_1(L/s)	FEV_1%M (L/s)	FEV0.5 (L)	FEV0.5%M (L)	PEF (L/s)	MEF75 (L/s)	MEF50 (L/s)	MEF25 (L/s)	FET (s)	Interpretation
1*													
2	Pre	0.64	0.64	0.37	67.97	0.57	89.06	1.37	1.35	1.18	0.97	1.26	Obstructive and pseudo-restrictive
	%Predicted	55.17	59.26	40.22				57.08	59.47	74.21	119.75		
	Post**												
3	Pre	1.12	1.10	0.97	97.38	0.65	59.09	2.10	2.08	1.71	0.79	2.20	Normal
	%Predicted	92.56	98.21	98.98				81.71	86.67	101.18	91.86		
	Post	1.05	1.03	0.92	96.17	0.72	69.90	1.92	1.67	1.46	0.38	1.17	
	%Predicted	86.78	91.96	93.88				74.71	69.58	86.39	44.19		
	%Change	-6.25	-6.36	-5.15	-1.24	10.77	18.30	-8.57	-19.71	-14.62	-51.90	-46.82	
4	Pre	1.06	1.06	0.93	91.67	0.70	66.04	2.18	1.73	1.17	0.52	1.78	Normal
	%Predicted	81.54	87.60	88.57				79.85	67.84	65.36	57.14		
	Post	1.07	1.07	0.96	91.03	0.74	69.16	2.29	1.89	1.26	0.57	2.00	
	%Predicted	82.31	88.43	91.43				83.88	74.12	70.39	62.64		
	%Change	0.94	0.94	3.23	-0.70	5.71	4.73	5.05	9.25	7.69	9.62	12.36	
5	Pre	0.50	0.44	NR	NR	0.41	93.18	1.10	1.07	0.84	0.52	0.84	Pseudo-restrictive
	%Predicted	54.35	53.01					55.00	55.73	62.69	76.47		
	Post**												
6***	Pre	0.67	0.93	0.81	87.33	0.60	64.52	2.35	1.55	0.92	0.46	2.31	Normal
	%Predicted		117.42	103.85					170.33				
	Post**												
7	Pre	0.55	0.55	NR	NR	0.45	81.82	1.34	1.31	0.91	0.65	0.76	Restrictive
	%Predicted	53.92	59.14					60.91	62.68	62.33	87.84		
	Post**												
8	Pre	0.69	0.65	0.65	100.00	0.50	76.92	1.42	1.39	0.93	0.58	1.81	Restrictive
	%Predicted	65.71	67.71	77.38				63.11	65.26	62.42	76.32		
	Post	0.69	0.65	0.65	99.97	0.55	84.62	1.84	1.83	1.45	0.78	1.01	
	%Predicted	65.71	67.71	77.38				81.78	85.92	97.32	102.63		
	%Change	0	0	0	-0.03	10.00	10.00	29.58	31.65	55.91	34.48	-44.20	
9	Pre		1.21	0.81	66.86	0.48	39.67	0.97	0.23			7.4	Inconclusive
	%Predicted		111.01	85.26				48.21	40.68	52.41	76.19		
	Post**												
10	Pre		0.89	0.88	98.38	0.72	80.90	1.71	2.18	1.63	0.96	1.10	Restrictive
	%Predicted		68.46	79.28				61.29	83.85	89.07	103.23		
	Post		0.89	NR	NR	0.81	91.01	2.34	2.25	1.97	1.14	0.95	
	%Predicted		68.46					83.87	86.54	107.65	122.58		
	%Change		0			12.50	12.50	36.84	3.21	20.86	18.75	-13.64	
11	Pre	0.63	0.63	NR	NR	0.62	98.41	1.77	1.63	1.61	1.02	0.78	Mixed
	%Predicted	65.63	70.79					86.34	83.16	117.52	145.71		
	Post	0.66	0.64	NR	NR	0.61	95.31	1.75	1.71	1.48	1.21	0.68	
	%Predicted	68.75	71.91					85.37	87.24	108.03	172.86		
	%Change	4.76	1.59			-1.61	-3.15	-1.13	4.91	-8.07	18.63	-12.82	

%Predicted: percentage predicted, Pre: pre-bronchodilator, Post: post-bronchodilator, %Change: percentage change between pre-and post-bronchodilator administration, SVC: slow vital capacity, FVC: forced vital capacity, FEV_1: forced expiratory volume in the first second, FEV_1%M: FEV_1 as a percentage of maximal VC, FEV.5: FEV in 0.5 seconds, FEV.5%M: FEV in 0.5 seconds as a percentage of maximal VC, PEF: peak expiratory flow rate, MEF75, 50, 25: maximal expiratory flowrate at 75%, 50% and 25% of FVC, NR: not recorded.

** Participant 1 refused to perform spirometry; ** Post-bronchodilator spirometry not performed *** GINA reference values used to calculate the predicted value*

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