Original Article
Iranian Journal of Otorhinolaryngology, Vol.38(5), Serial No.148, Sep-2026

Assessment of Pulmonary Functions in Adenotonsillar Hypertrophy Patients Using a Newer Modality of Forced Oscillation Technique

*Vidya Shekar[1], Krishnaswamy Kothandapani Shyamala[2], Ashwini Shastry[1], Soumya Vedavyasa[3]

Abstract

Introduction:

Adenotonsillar hypertrophy (ATH) is a common cause of upper airway obstruction in the paediatric population, resulting in sleep disturbances, chronic airway obstruction, and potential cardiopulmonary complications. The Forced Oscillation Technique (FOT) is a sensitive, non-invasive method for assessing pulmonary function and detecting abnormalities of the peripheral airways.

Materials and Methods:

This prospective pre–post cohort study included 35 patients aged 5–20 years with ATH who underwent FOT assessment before and six weeks after adenotonsillectomy. The parameters evaluated included total airway resistance (R5), central airway resistance (R20), peripheral airway resistance (R5–R20), reactance (X5), area of reactance (Ax), and resonant frequency (Fres).

Results:

Significant postoperative improvements were observed in R5 (0.46 ± 0.25 to 0.41 ± 0.25 kPa/L/s; $p = 0.001$), R20 (0.35 ± 0.19 to 0.30 ± 0.18 kPa/L/s; $p = 0.001$), X5 (−0.24 ± 0.16 to −0.12 ± 0.13 kPa/L/s; $p < 0.001$), Ax (2.93 ± 2.30 to 2.08 ± 1.71 kPa/L/s; $p < 0.001$), and Fres (24.89 ± 6.75 to 22.30 ± 6.00 Hz; $p < 0.001$). Although R5–R20 improved (0.10 ± 0.10 to 0.09 ± 0.10 kPa/L/s), the change was not statistically significant ($p = 0.427$). As R5–R20, X5, and Ax reflect peripheral airway function, improvements in these parameters suggest enhanced peripheral airway function following adenotonsillectomy. No significant association was found between pulmonary function and the degree of adenoid or tonsillar hypertrophy.

Conclusion:

FOT effectively detected improvements in pulmonary function following adenotonsillectomy and may be a valuable tool for evaluating respiratory changes in patients with ATH. Larger studies are warranted to better define its clinical utility.

Keywords: Adenotonsillar hypertrophy, Forced oscillation technique, Pulmonary function tests, Upper airway obstruction, Adenotonsillectomy

Received date: 26 May 2026
Accepted date: 03 Aug 2026

****Please cite this article;*** *Shekar V, Shyamala KK, Shastry A, Vedavyasa S. Assessment of Pulmonary Functions in Adenotonsillar Hypertrophy Patients Using a Newer Modality of Forced Oscillation Technique. Iran J Otorhinolaryngol. 2026:38(5):301-309. Doi: 10.22038/ijorl.2026.95645.4147*

[1]*Department of Ent, Dr B R Ambedkar Medical College, Bengaluru, India.*
[2]*Department of Respiratory Medicine, Dr B R Ambedkar Medical College, Bengaluru, India.*
[3]*Department Of Ent, Apollo Hospital Bannerghatta Roag, Bengaluru, India.*
****Corresponding author:*** *E-mail: vidya.6.s@gmail.com*

Introduction

Adenotonsillar hypertrophy (ATH) is a common condition in the paediatric population (1,2). It is the leading cause of upper airway obstruction in children (3). ATH contributes to chronic upper airway obstruction and sleep disturbances (4,5) Abnormal breathing patterns associated with ATH may result in hypoxia, hypercarbia, and elevated bicarbonate levels (6), leading to cardiopulmonary complications (7). If left untreated, ATH may lead to cor pulmonale, pulmonary hypertension, reduced alveolar ventilation, right ventricular dilatation**,** and heart failure (8-10) Behavioural and cognitive problems have also been reported in affected patients (11-15). These complications associated with upper airway obstruction can be reversed following adenotonsillectomy, resulting in significant improvements in patients' quality of life (16). Most previous studies have used spirometry or peak expiratory flow measurement to assess pulmonary function and have reported significant improvements following adenotonsillectomy (3,7,17-19). However, these techniques have several limitations. Forceful inspiratory and expiratory manoeuvres require good patient cooperation, making spirometry difficult to perform in children aged <5 years, older adults, and individuals with physical or cognitive impairments (20).

The Forced Oscillation Technique (FOT) is a newer, non-invasive modality for assessing pulmonary function. It measures lung function by superimposing pressure oscillations of single-frequency sound waves on normal tidal breathing. The technique measures respiratory impedance (Zrs), which comprises respiratory resistance (Rrs) and reactance (Xrs), across a range of frequencies, thereby providing information on the mechanical properties of the airways and lung parenchyma (20). Unlike spirometry, FOT requires only quiet tidal breathing, making it easier to perform and requiring considerably less patient effort and cooperation. One of its major advantages over spirometry is its greater sensitivity in detecting peripheral airway obstruction and early airway abnormalities (20). To the best of our knowledge, no previous study has evaluated pulmonary function in patients with adenotonsillar hypertrophy using FOT. Therefore, the present study aimed to assess pulmonary function in patients with adenoid and/or tonsillar hypertrophy and to evaluate the effect of adenotonsillectomy using the Forced Oscillation Technique.

Materials and Methods

A prospective pre–post cohort study was conducted in the Department of Otorhinolaryngology at a tertiary care teaching hospital after obtaining approval from the Institutional Ethics Committee. A total of 35 patients aged 5–20 years were enrolled between July 2025 and December 2025 after obtaining written informed consent from the patients or, in the case of children, from their parents or legal guardians. The sample size was calculated using the two-tailed paired t-test formula: $n = (Z_{1-\alpha/2} + Z_{1-\beta})^2/d^2$.

A detailed medical history was obtained, followed by a comprehensive ENT examination. Patients with a previous history of asthma or symptoms suggestive of asthma (shortness of breath, cough, wheeze, or dyspnoea), acute or chronic upper or lower respiratory tract infection, pulmonary tuberculosis or other infectious lung diseases, chest wall disease, other causes of nasal obstruction (such as an obstructive deviated nasal septum or nasal masses), a history of smoking, or previous treatment with allergen-specific immunotherapy were excluded from the study. A lateral plain radiograph of the nasopharynx was obtained in all patients to assess adenoid hypertrophy. Tonsillar hypertrophy was graded clinically using the Brodsky grading system, in which Grade 1 represents <25% obstruction of the oropharyngeal airway by tonsillar tissue, Grade 2 represents 26–50%, Grade 3 represents 51–75%, and Grade 4 represents >75% obstruction. Adenoid hypertrophy was graded using the Cohen and Konak radiological grading system, based on the adenoid-to-nasopharyngeal ratio. Grade 1 corresponds to a ratio of 0–25%, Grade 2 to 25–50%, Grade 3 to 50–75%, and Grade 4 to >75%. Patients were counselled regarding surgery and subsequently underwent adenoidectomy, tonsillectomy, or adenotonsillectomy under general anaesthesia, as indicated. FOT assessment was performed immediately before surgery and repeated six weeks postoperatively. The FOT assessments were performed in the Pulmonology Outpatient

Department by a trained technician. Patients were seated comfortably, and the FOT mouthpiece was positioned at an appropriate height to achieve slight neck extension. A tight seal was maintained between the lips and the mouthpiece to prevent air leakage. The patient's cheeks were firmly supported by either the patient or an assistant (Fig. 1). Patients were instructed to breathe normally and relax throughout the procedure. Each recording lasted 30–45 seconds, during which approximately 120–150 sound impulses were delivered to the lungs. Respiratory resistance and reactance were measured over a frequency range of 5–20 Hz. A Pulmoscan FOT system (JK Medical Systems), calibrated using Unit Pulmo 03, was used for all measurements. The parameters evaluated included R5 (total airway resistance), R20 (large airway resistance), R5–R20 (peripheral airway resistance), X5 (reactance representing the elastic recoil of the peripheral airways), Fres (the resonant frequency at which respiratory impedance becomes purely resistive), and Ax (the area of reactance, reflecting respiratory compliance and peripheral airway patency).

Statistical analysis was performed using SPSS version 29. Categorical variables were expressed as frequencies and percentages, whereas continuous variables were expressed as means ± standard deviations. The Kolmogorov–Smirnov test was used to assess the normality of continuous variables. Preoperative and postoperative measurements were compared using the paired Student's t-test. A p value of <0.05 was considered statistically significant. Associations between the grades of adenoid and tonsillar hypertrophy and pulmonary function parameters were also analysed for statistical significance.

Fig. 1. Representative clinical image of the study sample

Results

Our study included 35 patients aged 5–20 years. Although most previous studies evaluating pulmonary function in adenotonsillar hypertrophy have focused on paediatric populations, we included patients up to 20 years of age because, in our setting, a substantial proportion of patients aged 15–20 years also presented with symptomatic adenotonsillar hypertrophy. The majority of participants belonged to the 10–15-year age group (42.9%), followed by the 5–10-year and >15-year age groups (28.6% each). There were 20 (57.1%) males and 15 (42.9%) females. Most patients had experienced symptoms for 1–5 years (68.5%), followed by 6–10 years (17.1%), while 11.4% had symptoms for less than 1 year. Tonsillar hypertrophy was graded using the Brodsky classification. Grade 3 tonsillar hypertrophy was the most common finding (54.3%), followed by grade 2 (22.9%) and grade 4 (17.1%). Adenoid hypertrophy was graded radiologically on lateral nasopharyngeal radiographs using the Cohen and Konak classification. Grade 3 adenoid hypertrophy was the most frequent finding (42.9%), followed by grade 2 (28.5%) and grade 4 (22.9%). Pulmonary function was assessed in all patients using the Forced Oscillation Technique (FOT) on the day before surgery and at six weeks postoperatively.

Significant postoperative improvement was observed in the FOT parameters R5, R20, X5, Ax and Fres ($p < 0.05$). Although R5–R20 also demonstrated postoperative improvement, the difference did not reach statistical significance (Table 1).

Table 1. (FOT parameters pre-surgery and post-surgery in Mean and SD with t-test comparison)

		Mean	Std. Deviation	t-test	P-Value
R5 (Kpa/L/s)	Pre-surgery	.45817	.247599	3.756	0.001
	Post-surgery	.40783	.245436		
R20 (Kpa/L/s)	Pre-surgery	.34854	.181815	3.761	0.001
	Post-surgery	.303423	.1777193		
R5-R20 (Kpa/L/s)	Pre-surgery	.10314	.096848	.803	0.427
	Post-surgery	.0938769	.11319099		
AX (Kpa/L/s)	Pre-surgery	2.92946	2.326287	3.975	0.0001
	Post-surgery	2.0823274	1.71361489		
X5 (Kpa/L/s)	Pre-surgery	-.24369	.162621	-6.864	0.0001
	Post-surgery	-.11471	.134243		
Fres (Hz)	Pre-surgery	24.8911	6.75150	10.455	0.0001
	Post-surgery	22.2917	5.99182		

The greatest mean improvement in parameters reflecting peripheral airway function (X5, Ax and R5–R20) was observed in patients aged 5–10 years. In contrast, parameters reflecting total and central airway resistance (R5 and R20) showed the greatest improvement in patients aged >15 years. However, these differences were not statistically significant. No statistically significant differences in postoperative improvement were observed between male and female patients. Patients with a symptom duration of 1–10 years demonstrated greater improvement in most FOT parameters than those with symptoms lasting less than 1 year or more than 10 years. However, the greatest improvement in R5–R20 was observed in patients with symptoms of more than 10 years' duration. When postoperative changes in pulmonary function were analysed according to the grade of tonsillar hypertrophy, patients with grade 3 and grade 4 disease demonstrated greater improvement than those with lower grades; however, these differences were not statistically significant. Similarly, patients with grade 3 and grade 4 adenoid hypertrophy showed greater postoperative improvement in FOT parameters than those with lower grades, although the differences were not statistically significant (Tables 2–7).

Table 2. (R5 comparison pre and post-surgery according to age, gender, duration of symptoms, various grades of adenoid and tonsillar hypertrophy in terms of Mean and Mean difference)

R5 (kpa/L/s)		Mean		Mean Difference
		Pre surgery	Post-surgery	
AGE	5-10	.608	.567	-0.041
	10-15	.464	.421	-0.043
	15+	0.300	0.229	-0.071
Gender	F	0.494	0.445	-0.049
	M	0.431	0.38	-0.051
Duration	< 1	.368	.335	-0.033
	1 – 5	.489	.434	-0.055
	6 – 10	.474	.421	-0.053
	11+	-.013	-.012	0.001
Grade oF Adenoid	Grade I	.207	.204	-0.003
	Grade Ii	.308	.281	-0.027
	Grade Iii	.368	.324	-0.044
	Grade Iv	.540	.508	-0.032
Grade oF Tonsil	Grade I	.182	.123	-0.059
	Grade Ii	.537	.482	-0.055
	Grade Iii	.504	.432	-0.072
	Grade Iv	.299	.202	-0.097

Table 3. (R20 comparison pre and post-surgery according to age, gender, duration of symptoms, various grades of adenoid and tonsillar hypertrophy in terms of Mean and Mean difference)

R20 (kpa/L/s)		Mean		Mean difference
		Pre surgery	Post-surgery	
AGE	5-10	.448	.3909	-0.0571
	10-15	.354	.3251	-0.0289
	15+	.241	.1835	-0.0575
Gender	F	0.384	0.3387	-0.0453
	M	0.322	0.2769	-0.0451
Duration	< 1	0.281	0.2402	-0.0408
	1 - 5	0.368	0.3221	-0.0459
	6 - 10	0.371	0.3233	-0.0477
	11+	0.026	-0.012	-0.038
Grade of Adenoid	Grade I	.182	.1820	0
	Grade Ii	.373	.3215	-0.0515
	Grade Iii	.292	.2224	-0.0696
	Grade Iv	.416	.4013	-0.0147
Grade of Tonsil	Grade I	.140	.1255	-0.0145
	Grade Ii	.372	.3521	-0.0199
	Grade Iii	.424	.3464	-0.0776
	Grade Iv	.243	.1513	-0.0917

Table 4. (R5-R20 comparison pre and post-surgery according to age, gender, duration of symptoms, various grades of adenoid and tonsillar hypertrophy in terms of Mean and Mean difference)

R5-R20 (kpa/L/s)		Mean		Mean difference
		Pre surgery	Post-surgery	
AGE	5-10	.160	.17556	0.01556
	10-15	.095	.09007	-0.00493
	15+	.058	.01791	-0.04009
Gender	F	0.11	0.10682	-0.00318
	M	0.098	0.08417	-0.01383
Duration	< 1	0.081	0.0945	0.0135
	1 – 5	0.112	0.10813	-0.00387
	6 – 10	0.105	0.09793	-0.00707
	11+	-0.038	-0.275	-0.237
Grade of Adenoid	Grade I	0.025	0.0115	-0.0135
	Grade Ii	0.12	0.10985	-0.01015
	Grade Iii	0.1012	.0770	-0.0242
	Grade Iv	0.124	0.10711	-0.01689
Grade of Tonsil	Grade I	0.03	0.025	-0.005
	Grade Ii	0.06	0.05	0.01
	Grade Iii	0.121	0.101	-0.02071
	Grade Iv	0.135	0.113	-0.0225

Table 5. (AX comparison pre and post-surgery according to age, gender, duration of symptoms, various grades of adenoid and tonsillar hypertrophy in terms of Mean and Mean difference)

AX(kpa/L/s)		Mean		Mean difference
		Pre surgery	Post-surgery	
Age	5-10	3.951	2.28990	-1.6611
	10-15	2.989	2.38110	-0.6079
	15+	1.820	1.42660	-0.3934
Gender	F	3.620	2.32575	-1.29425
	M	2.412	1.89976	-0.51224
Duration	< 1	1.679	1.23275	-0.44625
	1 - 5	3.466	2.41869	-1.04731
	6 - 10	1.982	1.55850	-0.4235
	11+	.732	.55100	-0.181
Grade of Adenoid	Grade I	1.018	.78650	-0.2315
	Grade Ii	2.2493	1.7692	-0.48
	Grade Iii	3.1962	2.3123	-0.884
	Grade Iv	3.759	2.36681	-1.39219
Grade of Tonsil	Grade I	1.375	.85100	-0.524
	Grade Ii	1.194	.84683	-0.34717
	Grade Iii	3.148	2.23966	-0.90834
	Grade Iv	4.101	2.94312	-1.15788

Table 6. (X5 comparison pre and post-surgery according to age, gender, duration of symptoms, various grades of adenoid and tonsillar hypertrophy in terms of Mean and Mean difference)

X5 (kpa/L/s)		Mean		Mean difference
		Pre surgery	Post surgery	
Age	5-10	-.267	-.071	0.196
	10-15	-.262	-.141	0.121
	15+	-.193	-.119	0.074
Gender	F	-.275	-.120	0.155
	M	-.220	-.111	0.109
Duration	< 1	-.192	-.122	0.07
	1 – 5	-.270	-.117	0.153
	6 – 10	-.203	-.116	0.087
	11+	-.054	-.021	0.033
Grade of Adenoid	Grade I	-.130	-.093	0.037
	Grade Ii	-.211	-.067	0.144
	Grade Iii	-.239	-.156	0.083
	Grade Iv	-.338	-.158	0.18
Grade of Tonsil	Grade I	-.132	-.059	0.073
	Grade Ii	-.136	-.048	0.088
	Grade Iii	-.268	-.126	0.142
	Grade Iv	-.295	-.152	0.143

Table 7. (FRES comparison pre and post-surgery according to age, gender, duration of symptoms, various grades of adenoid and tonsillar hypertrophy in terms of Mean and Mean difference)

FRES (Hz)		Mean		Mean difference
		Pre surgery	Post-surgery	
Age	5-10	27.40	24.59	-2.81
	10-15	23.54	20.74	-2.8
	15+	24.41	22.33	-2.08
Gender	F	24.37	21.52	-2.85
	M	25.29	22.87	-2.42
Duration	< 1	22.56	21.35	-1.21
	1 - 5	25.57	22.67	-2.9
	6 - 10	23.58	21.17	-2.41
	11+	25.85	23.65	-2.2
Grade of Adenoid	Grade I	23.51	22.08	-1.43
	Grade Ii	22.31	19.92	-2.39
	Grade Iii	27.33	24.41	-2.92
	Grade Iv	23.90	21.34	-2.56
Grade of Tonsil	Grade I	25.04	22.99	-2.05
	Grade Ii	23.15	21.06	-2.09
	Grade Iii	23.89	21.37	-2.52
	Grade Iv	28.55	25.22	-3.33

Discussion

Our study included 35 patients. Most participants belonged to the 10–15-year age group (42.9%), followed by the 5–10-year (28.6%) and >15-year (28.6%) age groups. There were 20 (57.1%) males and 15 (42.9%) females. In a study conducted by Rogha et al. in 2016, 40 patients (23 males and 17 females) underwent spirometric assessment of pulmonary function before and after adenoidectomy (24). Similarly, a study by Shantipriya et al. in 2023 included 30 patients (25). In the present study, most patients (68.5%) had experienced symptoms for 1–5 years, followed by 17.1% with a symptom duration of 6–10 years and 11.4% with symptoms lasting less than 1 year. A study by Singal et al. in 2022 reported a similar pattern, with 62.5% of their 40 participants having symptoms for 1–5 years (26). The majority of patients in our study had grade 3 tonsillar hypertrophy (54.3%). Similarly, Singal et al. reported grade 3 tonsillar hypertrophy in 92.5% of patients (26), while Rogha et al. observed grade 3 hypertrophy in 69% of patients (24). However, Samareh Fekri et al. reported grade 2 tonsillar hypertrophy as the most common finding (27). Radiological assessment of adenoid hypertrophy demonstrated that grade 3 hypertrophy was the most common (42.9%), followed by grade 2 (28.5%) and grade 4 (22.9%). These findings are consistent with those of Singal et al., who reported grade 3 adenoid hypertrophy in 57.5% and grade 2 hypertrophy in 40% of patients (26). The Forced Oscillation Technique (FOT) was performed in all patients before and after surgery to evaluate pulmonary function. To the best of our knowledge, this is the first study to utilise FOT in patients with adenotonsillar hypertrophy. Previous studies have primarily employed spirometry or the Mini-Wright peak flow meter. However, these techniques require greater patient cooperation and respiratory effort, are difficult to perform in younger children, and are less sensitive in detecting peripheral airway abnormalities (20). Uysal et al. evaluated pulmonary function using impulse oscillometry in patients with isolated adenoid hypertrophy (21). Although impulse oscillometry and FOT are based on similar principles, the instruments differ in calibration, and the study did not include patients with tonsillar hypertrophy. The FOT parameters evaluated in our study included R5 (total airway resistance), R20 (central airway resistance), R5–R20 (peripheral airway resistance), X5 (peripheral airway reactance reflecting tissue elastance and elastic recoil), Ax (area of reactance, reflecting peripheral airway function), and Fres (resonant frequency at which reactance equals zero) (20). All parameters except Fres were expressed in kPa/L/s, whereas Fres was expressed in Hz. All parameters were measured preoperatively and postoperatively and subsequently compared. Postoperative improvement was observed in all parameters, with statistically significant differences ($p < 0.05$) in all except R5–R20. Among these, R5–R20, X5 and Ax are considered indicators of peripheral airway function (20). Although Ax and X5 demonstrated significant postoperative improvement, the improvement in R5–R20 did not reach statistical significance. These findings suggest that peripheral airway function improves following the relief of upper airway obstruction by adenotonsillectomy. Nevertheless, larger studies are required to confirm these observations and provide more robust quantitative evidence. We also compared the postoperative improvement in FOT parameters with the severity of adenoid and tonsillar hypertrophy. Comparisons were performed across grades 1–4 for both adenoid and tonsillar hypertrophy. No statistically significant associations were identified ($p > 0.05$). Therefore, our findings do not demonstrate a relationship between the severity of adenotonsillar hypertrophy and the degree of pulmonary function impairment. However, Uysal et al. reported significantly higher R5, Fres and Ax values in patients with grade 4 adenoid hypertrophy than in those with grade 1 disease ($p < 0.001$) (21).

FOT is an emerging modality that offers a valuable alternative to spirometry. It has been used extensively to assess pulmonary function in conditions such as asthma and chronic obstructive pulmonary disease (COPD), but its application in upper airway obstructive disorders, including adenoid and tonsillar hypertrophy, remains limited (20). Although FOT is simple to perform and requires minimal patient cooperation, interpretation of the results requires specialised training and experience. Furthermore, the methodology has not yet been fully standardised, and reference values remain limited.[20] Nevertheless, FOT provides valuable information regarding respiratory mechanics and peripheral airway function, highlighting its potential utility in future clinical and research applications.The limitations of our study include the relatively small sample size, the lack of standardised reference values for FOT parameters, the short follow-up period, and the absence of subgroup analyses comparing patients with isolated adenoid hypertrophy, isolated tonsillar hypertrophy, and combined adenotonsillar hypertrophy. Although this is, to the best of our knowledge, the first study to evaluate pulmonary function using FOT in patients with adenotonsillar hypertrophy, larger prospective studies are required to validate these findings and establish stronger clinical associations.

Conclusion

Our study demonstrated a significant improvement in pulmonary function, particularly in parameters reflecting peripheral airway function, following adenotonsillectomy in patients with adenotonsillar hypertrophy. However, no significant association was identified between pulmonary function and the severity of adenoid or tonsillar hypertrophy. To the best of our knowledge, this is the first study to evaluate pulmonary function in patients with adenotonsillar hypertrophy using the Forced Oscillation Technique (FOT), providing a more detailed assessment of respiratory mechanics than conventional spirometry or peak flow measurement. These findings suggest that FOT may serve as a useful non-invasive tool for evaluating pulmonary function in patients with adenotonsillar hypertrophy. Nevertheless, larger prospective studies with longer follow-up are required to validate these findings, establish standardised reference values, and further define the impact of adenotonsillar hypertrophy on pulmonary function.

References

1. Khalifa MS, Kamel RH, Zikry MA, Kandil TM. Effect of enlarged adenoids on arterial blood gases in children. J Laryngol Otol. 1991;105:436–8.

2. Menashe VD, Farrechic C, Miller M. Hypoventilation and cor pulmonale due to chronic upper airway obstruction. J Pediatr. 1965;66:198-203.

3. Niedzielska G, Kotowski M, Niedzielski A. Assessment of pulmonary function and nasal flow in children with adenoid hypertrophy. Int J Pediatr Otorhinolaryngol. 2008;72:333-5.

4. Arens R, McDonough JM, Corbin AM, et al. Upper airway size analysis by magnetic resonance imaging of children with obstructive sleep apnea syndrome. Am J Respir Crit Care Med. 2003;167:65-70.

5. Rosen CL, Larkin EK, Kirchner HL, et al. Prevalence and risk factors for sleep-disordered breathing in 8- to 11-year-old children: association with race and prematurity. J Pediatr. 2003;142:383-9.

6. Kharb S, Yadav SPS, Singh H, Singh GP. Effect of adenotonsillectomy on arterial blood gases and acid-base balance. Int J Pediatr Otorhinolaryngol. 1998;43: 213–15.

7. Pires MG, Di Francesco RC, Grumach AS, Mello JF. Evaluation of inspiratory pressure in children with enlarged tonsils and adenoids. Braz J Otorhinolaryngol. 2005;71(5):598–601.

8. Leach J, Olson J, Hermann J, Manning S. Polysomnographic and clinical findings in children with obstructive sleep apnea. Arch Otolaryngol Head Neck Surg 1992; 118(7):741-4.

9. Brouillete RT, Fernbach SK, Hunt CE. Obstructive sleep Apnea in infants and children. J Pediatr 1982; 100(1): 31-40.

10. Abdu MH, Feghali JG. Uvulopalato-pharyngoplasty in a child with obstructive sleep apnea. J Laryngoloto 1988; 102 (06): 546–8.

11. Tal A, Leiberman A, Margulis G, Sofer S. Ventricular dysfunction in children with obstructive sleep apnea: radionuclide assessment. Pediatr Pulmonol. 1988;4:139–43.

12. Marcus CL, Greene MG, Carroll JL. Blood pressure in children with obstructive sleep apnea. Am J Respir Crit Care Med. 1998;157:1098–103.

13. Gozal D. Sleep-disordered breathing and school performance in children. Pediatrics.1998;102: 616-20.

14. O'Brien LM, Gozal D. Behavioral and neurocognitive implications of snoring and obstructive sleep apnea in children: facts and theory. Paediatr Respir Rev. 2002;3:3–9.

15. O'Brien LM, Mervis CB, Holbrook CR, Bruner JL, Klaus CJ, Rutherford J, et al. Neurobehavioral implications of habitual snoring in children. Pediatrics. 2004;114:44–9.

16. Ali NJ, Pitson D, Stradling JR. Effects of adenotonsillectomy on behavior and psychological functioning. Eur J Pediatr 1996;155: 56–62.

17. Maurizi M, Paludetti G, Todisco T, Dottorini M, Grassi V. Pulmonary function studies in adenoid hypertrophy. Int J Pediatr Otorhinolaryngol. 1980; 2(3):243–50.

18. Di Martino E, Mlynski G, Mlynski B. Effect of adenoid hyperplasia on nasal airflow. Laryngorhino-otology. 1998;77:272–4.

19. Banzatto MG, Grumach AS, Mello JF Jr, Di Francesco RC. Adenotonsillectomy improves the strength of respiratory muscles in children with upper airway obstruction. Int J Pediatr Otorhinolaryngol. 2010;74(8):860–3.
20. Brashier B, Salvi S. Measuring lung function using sound waves: role of the forced oscillation technique and impulse oscillometry system. Breathe (Sheff). 2015 Mar;11(1):57-65. doi: 10.1183/ 20734735. 020514. PMID: 26306104; PMCID: PMC 4487383.
21. Uysal P, Güleç Köksal Z, Gönenli Z, Doğan M, Şahin M. The impact of adenoid hypertrophy on pulmonary functions measured using impulse oscillometry in preschool-age children. Eur Arch Oto-Rhino-Laryngol Off J Eur Fed Oto-Rhino-Laryngol Soc EUFOS Affil Ger Soc Oto-Rhino-Laryngol - Head Neck Surg. 2023 Jan;280(1):207–17
22. Atar Bese S, Ozdemir O, Tuncerler G, Erge D, Uysal P. Do not ignore mouth breathing syndrome: respiratory functions are affected in early childhood. Rhinology. 2024 Dec 1;62(6):659–68.
23. Yadav SPS, Dodeja OP, Gupta KB, Chanda R. Pulmonary function tests in children with adenotonsillar hypertrophy. Int J Pediatr Otorhinolaryngol. 2003 Feb 1;67(2):121–5.
24. Rogha M, Amini J, Raisi M. Pulmonary Function after Adenotonsillectomy. Iran J Otorhinolaryngol. 2016 Nov;28(89):383-388. PMID: 28008388; PMCID: PMC5168569
25. Shanti Priya D, Aishwarya V, Shoba K. Assessment of pulmonary function test and quality of life in children with adenotonsillar hypertrophy. International Journal for Research Trends and Innovation (www.ijrti.org), ISSN:2455-2631, Vol.8, Issue 2, page no.246 - 249, February-2023
26. Singhal A, Kumar L, Agarwal VK, Bist SS, Agrawal N. Effect of Adenotonsillectomy on Peak Expiratory Flow Rate Among Children. Indian J Otolaryngol Head Neck Surg. 2022 Dec;74(Suppl 3): 6491-6496. doi: 10.1007/s12070-021-02748-w. Epub 2021 Jul 10. PMID: 36742536; PMCID: PMC 9895728.
27. Samareh Fekri M, Arabi Mianroodi A, Shakeri H, Khanjani N. Effects of Tonsil size on Pulmonary Function test Results after Tonsillectomy in Children. Iran J Otorhinolaryngol. 2016 Jan; 28(84): 61-6. PMID: 26878005; PMCID: PMC4735618.