Do not ignore mouth breathing syndrome: respiratory functions are affected in early childhood

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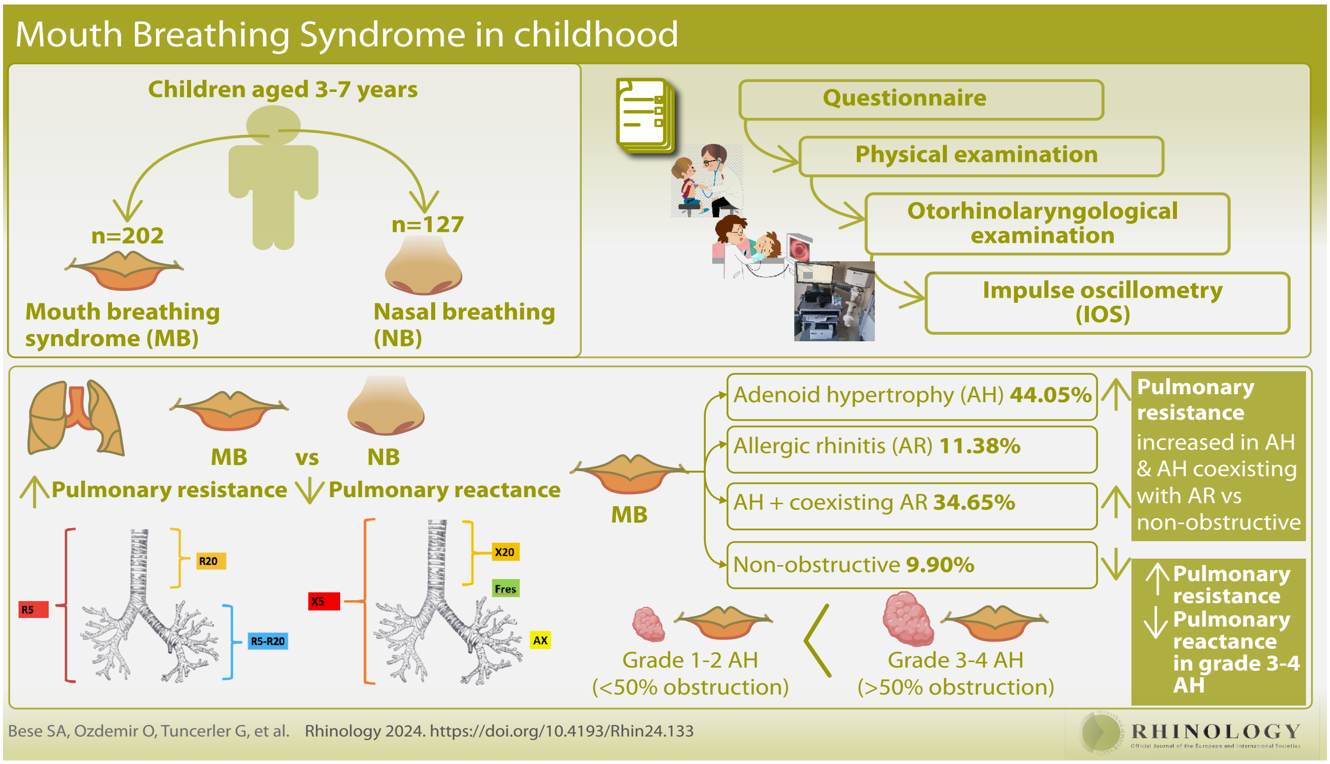
Rhinology 62: 6, 659 - 668, 2024
https://doi.org/10.4193/Rhin24.133



Abstract

Introduction: Impulse oscillometry (IOS) is a useful test for measuring pulmonary resistance and reactance from the early ages. We aimed to investigate the etiological factors of mouth breathing syndrome (MB), its effects on respiratory functions, and to compare the results with those of children with nasal breathing (NB). **Methods**: This prospective cross-sectional study investigated children aged 3-7 years with MB (n=202) and NB (n=127) admitted to the pediatric allergy clinic between January 2023-2024. The MB group was evaluated for etiological factors by means of otorhinolaryngological examination. Respiratory function tests were evaluated using IOS and were repeated two months after appropriate treatment. **Results**: Adenoid hypertrophy (AH-44.0%), allergic rhinitis (AR-11.3%) and AH co-existent with AR (34.6%) were the principal causes of MB. Entire airway resistance was higher, upper and lower airway reactance were lower in the MB group compared to the NB group. No difference was detected in terms of IOS parameters between the first and second visits of MB group. Upper and entire airway resistance parameters were higher in children with AH and AH co-existent with AR groups compared to the non-obstructive group. Entire airway resistance was higher, upper and lower airway reactance were lower, in children with adenoid size>50% compared to those with adenoid size<50%. **Conclusion**: Pre-school age children with MB exhibited higher airway resistance and lower airway reactance compared to the children with NB. This deterioration was more marked in children with greater AH. No significant improvement was observed in IOS after two months of medical or surgical treatment.

Key words: mouth breathing, allergic rhinitis, adenoids, respiratory function test, pediatrics

Introduction

Breathing is a vital function that normally occurs through the nose to filter, humidify, and warm inhaled air [1]. If respiratory functions are performed through the mouth for longer than six months, for any reason, this is known as mouth breathing (MB) syndrome, which may entail several complications [2-4]. As the process of MB continues, the tongue sits low, the strength of the cheek muscles increases, and the face assumes a 'V' shape, resulting in the appearance known as 'adenoid face' [3]. Overuse of accessory respiratory muscles results in a predominance of chest wall movement and a forward head posture during inspiration [4]. Impaired posture reduces the strength of the diaphragm and thoracic expansion. All these adaptation mechanisms are thought to adversely affect pulmonary ventilation [2].

MB can be seen at all ages but is more common in early childhood. The prevalence in previous studies ranges from 11% to 56% [5-8]. In its simplest and most common form, any condition that blocks the passage of air through the nose and nasopharynx can cause MB. Common etiological factors include adenoid hypertrophy (AH), allergic rhinitis (AR), anatomical-structural features and behavioral habits [3,9,10].

Although MB is very common in pre-school age children, respiratory function tests cannot be performed using conventional spirometry before the age of five because it is effort-dependent and requires a high level of cooperation. In addition, it does not provide sufficient information about peripheral airways [11]. Impulse oscillometry (IOS) is a standardized, non-invasive, practical alternative test that requires less effort than spirometry. It is highly useful for measuring entire and peripheral respiratory functions, particularly in pre-school age children who are unable to adapt to spirometry. IOS also provides more specific data concerning lung resistance, reactance, and peripheral airway obstruction [12,13]. Previous studies were detected decreased FEV1 levels on spirometry and low performance on six-minute walk test in patients with MB [14-16]. Studies have also used IOS in patients with AR and AH, and have detected increased pulmonary impedance at early ages [17-19]. However, we encountered no previous studies of the effects on respiratory functions in children with MB at early ages.

The purpose of this study was to use IOS to investigate the etiological factors, clinical conditions, and respiratory function tests of children with MB and to compare their respiratory function parameters with those of healthy children while also addressing different etiological causes.

Materials and methods

Study population

This prospective cross-sectional study was conducted at the pediatric allergy-immunology outpatient clinic of a tertiary referral center in Türkiye between January 2023 and January 2024. Children aged 3-7 of Caucasian ethnicity presenting to the hospital due to symptoms of nasal obstruction (such as snoring, MB, and sleep apnea), diagnosed with MB during physical examination by specialist physicians, and reported by their parents to have MB during the day and/or at night for more than six months were invited to participate. Demographic data were collected from patients who agreed to participate by means of a questionnaire (the MB group, n=202). Physical examinations were performed by pediatric allergy specialists. The patients were referred to the ear-nose-throat (ENT) department for otorhinolaryngological evaluations on the same day, and to the respiratory function test laboratory on the following morning. The patients were advised to receive appropriate treatment arranged by pediatric allergy specialists or the ENT department, and to attend a second visit after two months.

Sex-and age matched healthy controls were recruited from individuals attending general pediatric outpatient clinics for routine health workups (children with nasal breathing, the NB group, n= 127). General information was collected by means of a questionnaire. Physical examinations were also performed, and these children were referred to the respiratory function test laboratory on the same day.

The MB group was divided into four subgroups according to the most common etiological factors [Group 1, children with AH (n=89); Group 2, AR (n=23); Group 3, AH co-existent with AR (n=70); and Group 4, non-obstructive/ behavioral or anatomical factors (n=20)]. Children with AH were also subdivided depending on their adenoid tissue size; Grade I-II (adenoid size<50%, n=58) and Grade III-IV (adenoid size >50%, n=101).

Definitions

Diagnosis of MB was based on detailed histories from the families, including the presence of complaints such as breathing through the mouth at night or most of the day, snoring, and drooling from the mouth, and on observation of MB by a physician during physical examinations. 'Adenoid face' was defined as a small chin and open mouth [20].

Children in whom MB was not reported by the family, in whom the typical adenoid face appearance was not observed by a physician during physical examination, and who were capable of breathing easily through the nose were defined as NB.

AR was defined as the presence of symptoms of nasal itching, congestion, rhinorrhea, and sneezing, consistent with Allergic Rhinitis and its Impact on Asthma (ARIA) guidelines [21]. Inhalant allergen sensitization was investigated using the skin prick test to support the diagnosis of AR.

Adenoid tissue size was classified as described by Greenfeld et al. Accordingly, adenoids occupying up to 25% of the choana were classified as Grade I, adenoids occupying 25–50% of the choana as Grade II, adenoids obstructing 75% of the choana as Grade III, and adenoids obstructing at least 90% of the choana as Grade IV. Grade III and IV AH were evaluated as pathological [22].

Exclusion criteria

The exclusion criteria for the group MB were recurrent wheezing/asthma, history of chronic lung disease, first- and second-hand smoke exposure, chronic cardiac and neuromuscular disease, a history of low birth weight/premature birth/neonatal mechanical ventilation, malnutrition, obesity, malignancy, immune deficiencies, connective tissue disease, acute or chronic respiratory tract infections in the previous four weeks (including acute or chronic sinusitis), severe tonsil hypertrophy, a history of hospitalization or admission to the intensive care unit in the previous year, use of medications such as inhaled short-acting beta agonists, systemic steroids, anticholinergics, and decongestants, due to their potential effects on respiratory function tests. Exclusion criteria for the NB group included the presence of MB appearance in addition to the criteria listed above.

Study design

Pediatric allergy assessment

The MB group underwent a baseline physical examination including routine anthropometric measurements (height, weight, and body mass index). Demographic characteristics including general health information, clinical symptoms and, the patient's age, gender, medical history, atopy status, symptom frequency and duration, and family history were recorded using a questionnaire.

A simple questionnaire was employed to determine the general health status of the NB group, whose members also underwent a baseline physical examination including anthropometric measurements.

Otorhinolaryngological assessment

Nasal cavity and nasopharynx examinations were performed using a 3.5-mm diameter, 0-degree flexible rhino-fiberscope (KARL STORZ SE & Co. KG, Tuttlingen, Germany), and the images obtained were recorded. These were evaluated by the same otolaryngologist, who was blinded to the patients' physical examination findings. Adenoid tissue and, if present, its size and other clinical conditions (concha hypertrophy, nasal polyp, sinusitis etc.) that might cause MB were reported by ENT specialists. Medical or surgical treatment was planned by the ENT clinic in the light of international guidelines, based on the extent of the patient's AH and accompanying co-morbid conditions [23]. Information regarding the surgery and treatment decision was recorded in the patient files.

Pulmonary function test

The members of the MB group were referred to the respiratory function test laboratory on the morning of the following day, and the NB group on the same day, after physical examinations. Respiratory function testing commenced once the participants had been sitting calmly for at least five minutes.

Impulse oscillometry

A Jaeger MasterScreen IOS system (Jäeger, Wurzburg, Germany) was used to measure the input impedance of the respiratory system. This was performed in line with American Thoracic Society/European Respiratory Society guidelines [24]. The IOS technique is used to measure pulmonary resistance (R) and reactance (X). The flow signals were evaluated for 30s in a frequency range of 5 to 20Hz for amplitude differences to determine R and X values. The main parameters of IOS include resistances [R5, R20 R5-20 (resistance at 5 Hz minus resistance at 20Hz)] and reactance [X5, X20, resonant frequency (Fres) and reactance area (AX)] [13]. Higher frequencies of R (~20Hz), reflecting the larger airways, were regarded as representing resistance in the central airways. Lower frequencies of R (~5Hz) provided information about the totality of airways (both small and large). Peripheral (small) airway resistance was defined as R5-20 [25]. Fres is the intermediate frequency at which the total reactance is zero, which occurs when the capacitive and inertive pressure drops are equal. It decreases with age and increases in both restrictive and obstructive conditions. AX means the total reactance (area under the curve) at all frequencies between 5Hz and Fres, so this individual value constitutes all frequencies measured by IOS. As with X5, AX also provides information regarding peripheral airway obstruction [13]. Acceptable variability was 15%. The coherence thresholds were set to ≥0.6 at 5Hz and ≥0.8 at 20Hz [25,26]. R5, R20, X5, and X20 were transformed into z-scores from reference data to adjust the values for age and gender. R5-20, Fres, and AX were used as measured crude values due to the lack of references [27].

Treatment protocols

Patients diagnosed with AR were primarily treated with nasal steroids and, if clinically necessary, antihistamines according to ARIA guidelines [21]. Leukotriene receptor antagonists were recommended for patients who were unable and/or unwilling to use nasal steroids. The treatment of patients with adenoid hypertrophy was planned by the ENT specialist as surgical (adenoidectomy) or medical (nasal steroids, antihistamines and/or leukotriene receptor antagonists) according to the size of the adenoid tissue and the patient's clinic, taking into account the current guidelines on the subject [22,23].

Skin prick tests

Skin prick tests were performed on children with AR for aeroallergens using a prick test applicator (MedBlue One) and standardized glycerinated extracts from LOFARMA (Milan, Italy) applied to the flexural aspect of the forearm in line with standard guidelines. An induration diameter of >3mm was regarded as positive (1% weight/volume) [28].

Sample size

For statistical power analysis, due to the lack of studies evalu-

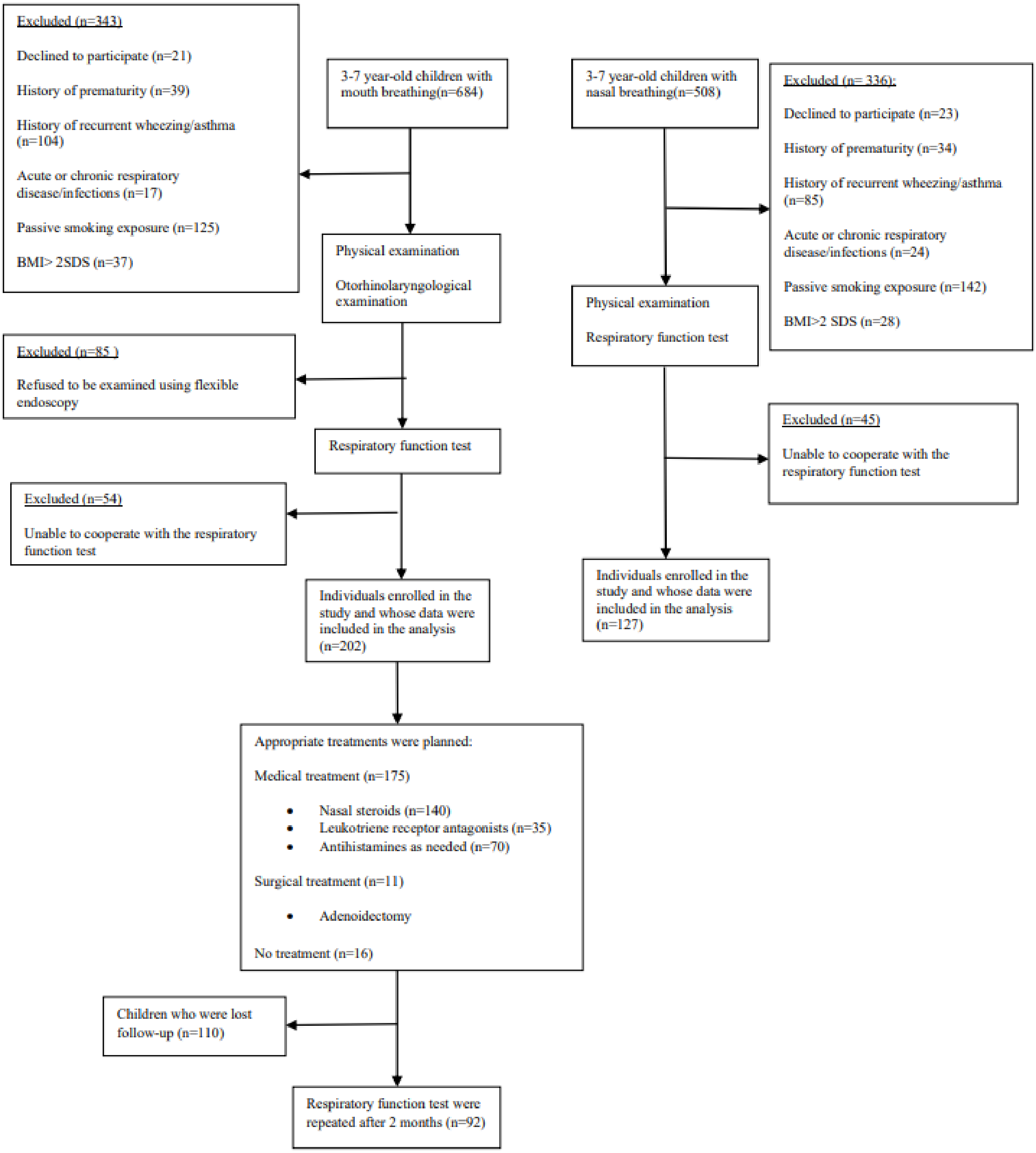


Figure 1. Study flowchart.

ating respiratory functions using IOS in children with MB, we calculated the sample size based on previous studies conducted using spirometry. The zFEV1 value adopted from Abate et al. was used to calculate the sample size (29). The difference between the two averages was moderate. A sample size of 210 was determined with an effect size of 0.45 alpha error probability of 0.05 and power=0.95 (105 MB and 105 NB).

Ethics

The study was approved by the institutional local research ethics committee (E2023/25). All participants took part voluntarily, and written informed consent was obtained from the parents of all children.

Statistical analysis

SPSS version 21.0 software (SPSS for Windows 21.0, IBM SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Categorical variables are presented as numbers (%) and continuous variables as mean±SD and median values (interquartile range-IQR). Univariate analyses involving categorical data were performed using the χ^2 test. Data from pulmonary function tests exhibiting parametric variables according to the Shapiro-Wilk normality test were analyzed using Student's t-test, and non-parametric variables using the Mann-Whitney U test (comparison between the MB and NB groups). The Kruskal-Wallis test was applied for non-parametric values among four groups. The Mann-Whitney U test was used for sub-group analysis, and p<0.008 was conside-

Table 1. Demographical parameters of children with mouth breathing and nasal breathing, and the etiological factors and treatment data of children with mouth breathing.

Demographical data	MB Group Children with mouth breathing (n=202)	NB Group Children with nasal breathing (n=127)	p value (p<0.05)
Sex (male), %(n)	58.9% (n=119)	57.4% (n=73)	0.798
Age (years), (mean±SD)	4.63±1.19	4.39±1.07	0.073
Weight, kg SDS, (mean±SD)	0.21±1.04	0.03±1.09	0.135
Height, cm SDS, (mean±SD)	0.19±1.03	0.21±1.26	0.895
BMI, kg/m² SDS, (mean±SD)	0.09±1.07	-0.06±1.12	0.210
Etiological factors related to mouth breathing			
Adenoid hypertrophy	44.0% (n=89)	N/A	N/A
Allergic rhinitis	11.3% (n=23)	N/A	N/A
Adenoid hypertrophy co- existent allergic rhinitis	34.6% (n=70)		
Non-obstructive causes (anatomical or behavioral)	9.9% (n=20)	N/A	N/A
Treatment data of children with mouth breathing			
Nasal steroids	69.3% (n=140)		
Antihistamines (as needed)	47.0% (n=95)		
Leukotriene receptor antagonists	17.3% (n=35)		
Adenoidectomy	5.4% (n=11)		
No treatment	7.9% (n=16)		

n, number; SDS, Standard deviation score; SD, standard deviation; N/A, not available; AH, adenoid hypertrophy; BMI, body mass index. p values <0.05 were regarded as significant. Categorical data were compared using the Chi-square test. Student's T test was used for parametric continuous data.

red significant with the Bonferroni correction. The Wilcoxon test was used for two non-parametric related samples (comparison of IOS values at the first and second visits). A p value <0.05 was considered statistically significant.

Results

There were 202 children with MB and 127 with NB included in the study. The study flowchart is shown in Figure 1. No difference was determined between the groups in terms of the demographic characteristics of sex or age, or z scores for weight, height, and body mass index (BMI) (p>0.05). In terms of the etiology of MB, AH was present in 78.7% of cases, AR in 46.0%, and non-obstructive (anatomical or behavioral) causes in 9.9%. All the patients diagnosed with allergic rhinitis had inhaled allergen sensitization on skin prick test. About treatment data, 69.3% of children were treated with nasal steroids, 47.0% antihistamines (as needed), 17.3% of them with leukotriene receptor antagonists, and 5.4% were treated with adenoidectomy (Table 1).

At IOS analysis, higher zR5, zR20, R5-20 (reflecting increased total, upper and peripheral airway resistance), higher Fres, and Ax (reflecting decreased peripheral airway reactance) and lower zX20 (reflecting decreased upper airway reactance) were observed in children with MB compared to those with NB (p=0.024, p=0.036, p=0.016, p<0.001, p=0.001, and p<0.001, respectively) (Table 2 and Figure 2).

No difference was detected in terms of IOS parameters between the first and second visits after appropriate treatment for etiological causes in the children with MB (p>0.05) (Table 3).

Examination of IOS values in the four sub-groups constituted according to the most common etiological factors, revealed a difference among the four groups in terms of zR5 and zR20 (p=0.002 and p=0.004 respectively). Subgroup analyses of these parameters revealed that the zR5 and zR20 parameters in groups 1 (AH) and 3 (AH coexistent with AR) were higher than those in group 4 (non-obstructive causes) (p<0.001, p=0.003, p<0.001, and p=0.001, respectively) (Table 4).

When the children with AH were grouped according to adenoid tissue sizes, zR5, zR20, R5-20 and AX values were higher, while zX20 values were lower, in children with Grade 3-4 AH compared to the Grade 1-2 AH group (p<0.001, p=0.03, p<0.01, p=0.06, and p=0.05, respectively) (Table 5).

Discussion

To the best of our knowledge this is the first study in the literature to evaluate pulmonary resistance and reactance by using IOS and to compare children with MB and NB with no underlying

Table 2. A comparison of impulse oscillometry parameters between children with mouth breathing and nasal breathing.

IOS parameters	MB Group Children with mouth breathing (n=202)	NB Group Children with nasal breathing (n=127)	p value (p<0.05)
zR5 (median IQR)	0.27 (-0.47 – 0.86)	-0.09 (-0.73 – 0.78)	**0.024**
zR20 (median IQR)	-0.20 (-0.70 – 0.23)	-0.37 (-0.89 – 0.14)	**0.036**
R5-20 (median IQR)	0.79 (0.69 – 0.94)	0.77 (0.60 – 0.91)	**0.016**
zX5 (median IQR)	0.55 (-0.55 – 2.20)	0.92 (-0.18 – 2.22)	0.397
zX20 (median IQR)	-2.66 (-3.57 – -1.75)	-1.09 (-2.40 – -0.35)	**<0.001**
Fres (median IQR)	25.00 (21.92 – 28.44)	22.31 (17.74 – 26.78)	**<0.001**
AX (median IQR)	2.67 (1.85 – 3.80)	2.15 (1.11 – 3.39)	**0.001**

IOS, impulse oscillometry; IQR, interquartile range; SD, standard deviation; R, resistance; X, reactance; Fres, resonant frequency; Ax, reactance area; n, number; z, z-score.Significant p values (< 0.05) are shown in bold. The Mann-Whitney U test was used for non-parametric continuous data.

Table 3. A comparison of impulse oscillometry parameters of children with mouth breathing at the 1st and 2nd visits.

IOS parameters	MB Group at the 1st visit (n=92)	MB Group at the 2nd visit (n=92)	p value (p<0.05)
zR5 (median IQR)	0.39 (-0.30 – 0.89)	-0.13 (-0.67 – 0.60)	0.059
zR20 (median IQR)	-0.13 (-0.60 – 0.38)	-0.31 (-0.79 – 0.17)	0.079
R5-20 (median IQR)	0.78 (0.69 – 0.93)	0.77 (0.66 – 0.91)	0.422
zX5 (median IQR)	0.42 (-0.73 – 2.52)	0.55 (-1.01 – 1.60)	0.241
zX20 (median IQR)	-2.66 (-3.75 – -1.75)	-2.94 (-3.74 – -1.89)	0.289
Fres (median IQR)	25.12 (22.11 – 28.83)	24.98 (22.27 – 28.37)	0.989
AX (median IQR)	2.88 (1.74 – 3.80)	2.58 (1.78 – 4.01)	0.421

IOS, impulse oscillometry; IQR, interquartile range; R, resistance; X, reactance; Fres, resonant frequency; Ax, reactance area; n, number; z, z-score. Significant p values (< 0.05) are shown in bold. Wilcoxon's test was used for two non-parametric related samples.

bronchial obstruction, asthma, or recurrent wheezing history. In terms of the etiology of MB, AH was the most common cause in 44.0% of cases, while AR was present in 11.3%, AH co-existent with AR in 34.6%, and non-obstructive causes in 9.9%. IOS analysis revealed high airway resistance (higher zR5, zR20, R5-20) and low airway reactance (lower zX20, higher Fres and AX) in the MB group compared to the NB group. No significant improvement in respiratory functions was observed after two months of appropriate treatment for each etiological cause. At sub-group analysis, pulmonary resistance was higher in children with AH and AH co-existent with AR than in the non-obstructive group. Pulmonary impedance was more impaired in children with adenoid sizes>50% than in those with adenoid sizes<50%.

Although MB or 'adenoid face' appearance is commonly associated with AH, allergic diseases are also an important etiological factor due to their high prevalence in society [30]. AH and AR were the most common causes of MB in the present study. Consistent with our results, a previous study investigating 205 children with MB and nasal congestion reported inhaled allergen sensitivity in 76% of the patients and Grade II-III-IV AH in 64% [31]. A population-based cross-sectional study applied a questionnaire to the parents of children aged 2-6 years. MB was found to be significantly associated with atopic dermatitis, as well as with asthma and AR [32]. The co-existence of AH and AR is quite common, and AR contributes to the increase in adenoid size [33-35]. We may therefore speculate that MB due to AH may facilitate the passage of inhaled allergens through the respiratory system and lead to an increase in the frequency of AR.

The only prospective case-control study about respiratory functions reported lower forced vital capacity (FVC) in children with MB than in those with NB [14]. A population survey from Japan reported that MB alone was associated with lower lung functions in individuals without asthma and/or allergic rhinitis [16]. In a cross-sectional study of school-age children, those with MB exhibited decreased maximal inspiratory pressure and maximal expiratory pressure, but no significant difference was observed in the six-minute walk test compared to children with NB [2]. However, an another study observed an increased respiratory

Table 4. A comparison of impulse oscillometry values in the children with mouth breathing sub-groups based on etiological factors.

IOS parameters	Group 1, Children with adenoid hypertrophy (n= 89)	Group 2, Children with allergic rhinitis (n= 23)	Group 3, Children with adenoid hypertrophy co-existent allergic rhinitis (n=70)	Group 4, Non-obstructive group (n=20)	p value
zR5 (median IQR)	0.52 (-0.39 - 1.23)	0.28 (-0.34 - 0.60)	0.15 (-0.34 - 0.86)	-0.61 (-1.14 - 0.39)	**0.002** 1-2=0.141 1-3=0.124 **1-4<0.001** 2-3=0.779 2-4=0.045 **3-4=0.003**
zR20 (median IQR)	-0.17 (-0.61 –0.38)	-0.26 (-0.70 - 0.22)	-0.13 (-0.67-0.23	-0.82 (-1.32- 0.30)	**0.004** 1-2=0.496 1-3=0.997 **1-4<0.001** 2-3=0.536 2-4=0.019 **3-4=0.001**
R5-20 (median IQR)	0.82 (0.71 – 1.01)	0.78 (0.65 - 0.81)	0.78 (0.67 - 0.95)	0.78 (0.64 - 0.87)	0.095
zX5 (median IQR)	0.55 (-0.92 – 2.30)	0.55 (0.01 - 2.77)	0.64 (-0.31 - 1.89)	0.71 (0.13 - 2.31)	0.881
zX20 (median IQR)	-2.84 (-4.26 – -1.89)	-2.18 (-3.28 – -1.26)	-2.62 (-3.56– -1.93)	-2.74 (-4.16- -1.75)	0.501
Fres (median IQR)	24.98 (22.39-29.14)	24.27 (20.59-26.99)	25.20 (21.82-28.55)	24.26 (22.21-27.54)	0.644
AX (median IQR)	3.02 (2.05-4.69)	2.12 (1.81- 3.17)	2.56 (1.82-3.57)	2.65 (1.63-3.01)	0.057

IOS, impulse oscillometry; IQR, inter quartile range; R, resistance; X, reactance; Fres, resonant frequency; Ax, reactance area; n, number; z, z-score. Significant p values(< 0.05) are shown in bold. The Kruskal-Wallis test was applied for non-parametric values among the foursub-groups. The Mann-Whitney U test was used for sub-group analysis, and p values <0.008 were considered significant with Bonferroni correction.

Table 5. A comparison of impulse oscillometry parameters between the groups established according to adenoid size (Grade I-II and Grade III-IV).

IOS parameters	Adenoid hypertrophy Grade I-II (n=58)	Adenoid hypertrophy Grade III-IV (n=101)	p value (p<0.05)
zR5 (median IQR)	-0.33 (-0.62 – 0.45)	0.56 (-0.14 – 1.26)	**<0.001**
zR20 (median IQR)	-0.39 (-0.71 – -0.13)	0.06 (-0.52 – 0.42)	**0.003**
R5-20 (median IQR)	0.73 (0.65 – 0.86)	0.86 (0.72 – 1.04)	**<0.001**
zX5 (median IQR)	0.39 (-0.55 – 1.66)	0.73 (-0.92 – 2.20)	0.972
zX20 (median IQR)	-2.52 (-2.97 – -1.68)	-3.01 (-4.37 – -1.89)	**0.005**
Fres (median IQR)	24.45 (22.17 – 26.39)	25.65 (22.08 – 31.17)	0.105
AX (median IQR)	2.42 (1.67 – 3.48)	3.23 (2.11 – 4.56)	**0.006**

IOS, impulse oscillometry; IQR, interquartile range; R, resistance; X, reactance; Fres, resonant frequency; Ax, reactance area; n, number; z, z-score. Significant p values(< 0.05) are shown in bold. The Mann-Whitney U test was used for non-parametric continuous data.

rate and decreased SpO2 in the six-minute walk test in children with MB compared to those with NB [15].

In the present study, children with adenoid sizes>50% exhibited more impaired respiratory impedance than those with sizes <50%. Our findings demonstrate that adenoid size is closely related to all and peripheral airway obstruction. Despite treatment appropriate to the etiology, we observed no improvement in respiratory functions after two months. Consistent with our results, a previous study investigating the effect of AH on respiratory function tests in children with mild asthma reported significantly lower FVC in children with Grade III-IV AH compared to those with Grade I-II. In this study, the age range was 6-14 years and the average age was 10.5 years [36]. In another study, pre- and postoperative spirometry measurements in children

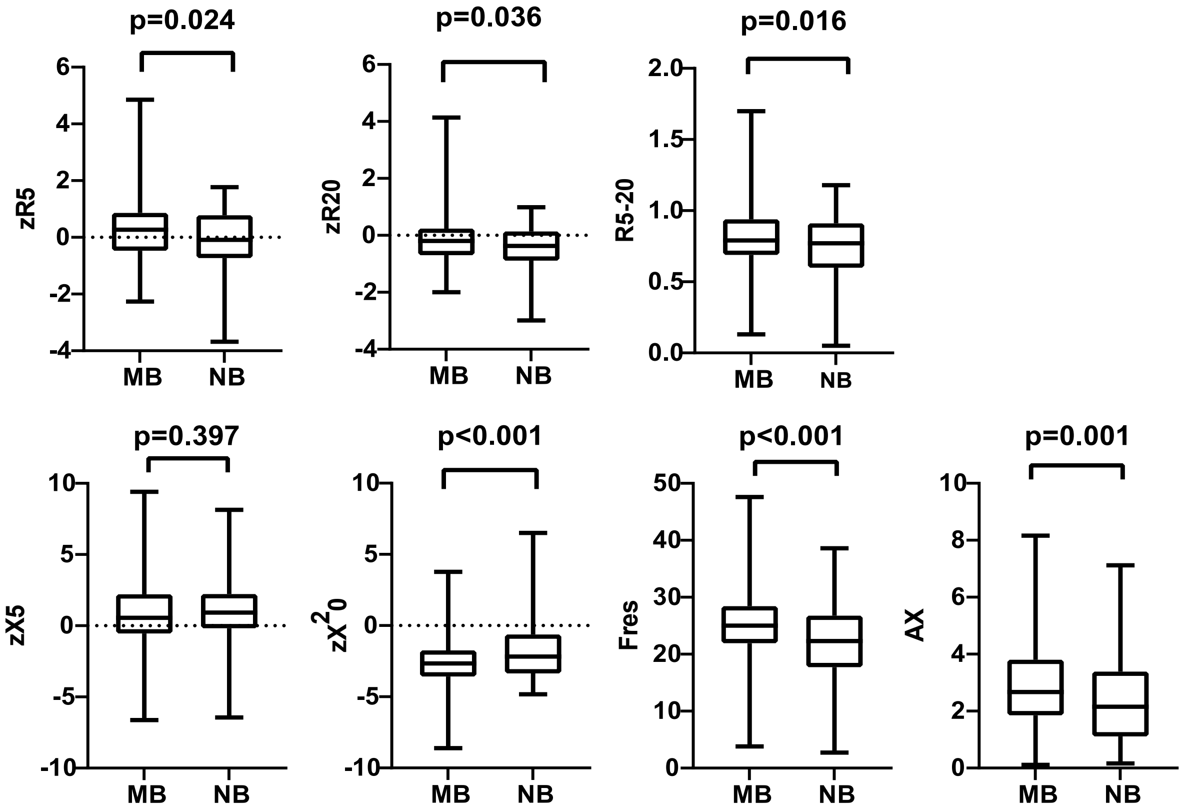


Figure 2. A comparison of impulse oscillometry parameters between children with mouth breathing and nasal breathing. *Statistically significant values were regarded as p values<0.05. MB, children with mouth breathing; NB, children with nasal breathing. Box and whisker plots were generated on GraphPad Prism 9.

with AH reported improved lung volumes postoperatively after 1.5 months, and that these became indistinguishable from those of healthy controls [37]. In another study, pulmonary impedance in children with Grade IV AH was worse than in those with lower grades, while an improvement in IOS parameters was achieved two months after adenoidectomy [17]. All these studies emphasize that patients' respiratory function tests should be taken into consideration according to their adenoid size. We may speculate that the two-month period of medical treatment in children with AH may not be as successful as adenoidectomy in improving respiratory functions. The presence of AR in a large proportion of patients with AH in the present study may have contributed to the lack of improvement in respiratory functions. In the studies described above, the cases that underwent adenoidectomy may have been more severe, and the success of the surgical treatment in improving respiratory functions may have been more evident.

We detected AR in approximately half of the children with MB. The impact of AR on airway functions has been well-known for decades, due to its close relationship with asthma and the common airway hypothesis. A previous study demonstrated mild reversible airway obstruction that could not be detected by means of spirometry in children with AR by using IOS [19]. The question is whether the process that starts with MB leads to airway reactivity over time, or whether the history of allergic respiratory disease starts with MB. This very much resembles the chicken or the egg causality dilemma.

The strengths of this study were that all children with MB were examined and carefully diagnosed by pediatric allergy and ENT specialists in a tertiary referral center. Careful endoscopic examination was performed on all children with MB for the diagnosis of AH and differential diagnoses. All cases were recently diagnosed MB with a history of at least six months. Skin prick tests were used for the diagnosis of allergen sensitization in children with AR. Additionally, all respiratory function tests were performed by an experienced nurse at the same time of day in to eliminate potential variability in airway reactivity. Furthermore, when selecting the patients to be included in the study, close attention was paid to the exclusion criteria to eliminate cofactors capable of impairing respiratory function tests. However, sufficient patients were carefully collected over an extended period, and real-life data were collected.

The principal limitation of this study is that the results cannot be generalized to the entire population because it was conducted in a single-tertiary referral center. The lack of z score for Fres, Ax, and R5-20 and higher than expected crude values for young children may have affected our results. We also had to exclude many patients due to the presence of numerous cofactors capable of affecting the pulmonary function tests. The fact that second hand smoking exposure could not be measured quantitatively was also among our limitations. But a decision was based on the history by questioning the parents in detail.

Conclusion

This is the first study to investigate the effect of MB on pulmonary impedance in children. We were surprised that the respiratory functions of children with MB were affected to such a significant extent. This deterioration was associated with the size of adenoids, but no significant improvement in respiratory functions was observed two months after appropriate medical or surgical treatment. Deterioration in respiratory functions starting at such an early age also reveals the importance of open-mouth breathing. MB should be recognized as a disease with a complex etiology and complications. We therefore hope that this study will enhance readers' awareness of the condition.

Acknowledgements

The authors are greatly indebted to specialist nurse Durdane Kavak for her skill in performing the respiratory function tests and her attentive attitude toward the children and their parents. The authors are also grateful to Professor Aylin Eryılmaz and her ENT team for their meticulous otorhinolaryngological examinations.

Authorship contribution

SAB and PU: conceptualization, investigation, methodology, validation, formal analysis, supervision, data curation, writing original draft, review and editing; OO, GT and DE: conceptualization, investigation, methodology, validation, review and editing.

Conflict of interest

The authors declare that they have no conflict of interest.

Funding

This research received no specific grant from any funding agencies.

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Rhinology 62: 6, 659 - 668, 2024
https://doi.org/10.4193/Rhin24.133

Received for publication:
March 25, 2024
Accepted: August 14, 2024

Associate Editor:
Sietze Reitsma