National Journal of Physiology, Pharmacy and Pharmacology

RESEARCH ARTICLE

Establishing norms for nasal spirometry

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Received: April 03, 2018; **Accepted:** April 26, 2018

ABSTRACT

Background: Conventional spirometry in which air flows through the mouth is used to detect obstructive airways disease. If air is made to flow through the nose only, obstructive disorders of nose-nasopharynx region may be detected. In this study, this was carried out by a simple modification at the patient end of the spirometer tube that enabled the patient to breathe out through the nose only or through the nose and mouth. **Aims and Objective:** The main aim of the current study is to compare oronasal and nasal spirometry measurements in healthy individuals and establish normal values for nasal spirometry. **Materials and Methods**: A total of 600 healthy individuals were divided into three groups based on age: Group 1: 6–15 years, Group 2: 16–35 years, and Group 3: 36–50 years. Each group contained 200 subjects. All subjects underwent two sets of measurements: (1) Oronasal spirometry and (2) nasal spirometry. Forced vital capacity (FVC), forced expiratory volume in first second (FEV1), FEV1/FVC%, Forced expiratory time (FET), peak expiratory flow rate, forced inspiratory flow at 50% of inspired volume during FVC test, forced expiratory flow at 50% of expired volume during FVC test, and peak inspiratory flow rate were evaluated in all groups. **Results:** In the age group of 16–35 years, all the parameters are significantly less in nasal spirometry when compared to oronasal spirometry. In the 36–50 years group, the results were similar except for FET which did not differ significantly in females. In the age group of 6–15 years, differences in FET were not significant in both the sexes. In males, FVC, FEV1, and FEV1% were significantly less for nasal spirometry, but in females, there was no significant difference. **Conclusion:** Significant differences were observed between many oronasal and nasal parameters. This indicates that there is a difference between airflow through the mouth and airflow only through the nose in healthy individuals. These differences could be exaggerated in persons with obstruction in the nose–nasopharynx region. Since the instrument is a portable one, many exciting possibilities are open to investigation.

KEY WORDS: Oronasal Spirometry; Nasal Spirometry; Nasopharynx; Nasal Obstruction

INTRODUCTION

In general, lung diseases are subdivided into obstructive airways diseases and restrictive chest diseases. For diagnosis of respiratory disorders, spirometry and peak flow meter were the basic tests used earlier; they are mostly replaced by electronic spirometer now. Obstructive airway disease is typically seen in bronchial asthma and bronchitis and is due to blockage of 5^{th}–7^{th} generation of bronchioles. The contribution of these airways toward airways resistance is explained by the Poiseuille's equation for laminar flow of gas or liquid in cylindrical tubes of different diameter. Methods to assess this type of lower respiratory obstruction are available and have been standardized.

Access this article online	
Website: www.njppp.com	Quick Response code
DOI: 10.5455/njppp.2018.8.0414226042018	

While breathing through the mouth, air which passes through the mouth and oropharynx does not encounter any resistance since dimensions of this cavity are much more than the larynx and the trachea which are the widest portions of the respiratory tree. During normal breathing through the nose,

air passes through the nose and nasopharynx. Airflow through the nose is not as free as it is through the mouth due to the narrowness of the nasal cavities and presence of the three turbinates projecting into the nasal cavity. Many factors can reduce the size of the nasal cavity still further. These include width of the nose which determined by the bone and cartilage structure, vasodilation of the nasal mucosa, and presence of thick mucus commonly seen during a cold and in nasal allergies, deviated nasal septum (DNS), and extensive nasal polyps. The nasopharynx region is much wider, but even this may be narrowed in the presence of enlarged adenoids which is fairly common in children.

Due to its anatomy, the nose–nasopharynx region may manifest some impediment to airflow even in healthy persons. This could be further aggravated in disorders which narrow the nose–nasopharynx region. A simple cold is the most commont example of temporary obstruction in this region, and everyone has experienced the uncomfortable feeling caused by this obstruction. More permanent and pathological obstruction of the nose–nasopharynx region is seen in chronic nasal allergy, DNS, adenoids, obstructive sleep apnea (OSA), and rarely in nasopharyngeal carcinoma. These patients, especially those with adenoids, become mouth breathers if the obstruction is significant. OSA patients are known to become hypoxic. Similarly, obstruction due to each of these disorders is associated with its own complications. In the investigation and treatment of these disorders, it may be significant to assess the degree of nose–nasopharynx obstruction. There is no simple and accurate method for this assessment.

Since the nose–nasopharynx region is not a tube and has a wider diameter than the trachea, it does not offer resistance as envisaged by the Poiseuille's equation. Besides, in conventional spirometry and with the peak flow meter, either a mouthpiece or face mask is used while the nose is clamped so that airflow is through the mouth. These tests bypass the nose–nasopharynx and are therefore not influenced by obstruction in this region.

Studies which have been used to assess obstruction of nose–nasopharynx region fall into two groups: (a) the normal tests used to assess obstructive airways disease and (b) tests especially designed to assess obstruction in the nose–nasopharynx region.

Conventional oral spirometry in pre- and post-surgery children with adenotonsillar hypertrophy showed significant changes in forced vital capacity (FVC), FEF_{25-75}, PEF, and MEF_{25}.[1,2] In OSA patients, there were no significant changes shown in FVC, forced expiratory volume in first second (FEV1) and FVC/FEV1% by conventional oral spirometry.[3]

The second group of tests used to assess nasopharyngeal obstruction is nasopharyngeal video endoscopy and lateral cephalometric radiography. In mouth breathing children, lateral cephalometric radiography using two-dimensional images could only distinguish possible obstruction of nasopharynx; video endoscopy with a flexible fiberscope inserted into the nasal cavity gave details about color, texture, and volume of nasopharynx and was more reliable.[4] The disadvantage of the first method is that it exposed children to X-rays; the second is more invasive.

It is obvious that there is no simple and efficient method to assess obstruction of the nose–nasopharynx region. The electronic spirometer offers many parameters not present in the conventional spirometer. If air is made to flow through the nose–nasopharynx region instead of the mouth, it is possible that different set parameters which help in diagnosis/assessment of obstruction in this region may be found. The present study is a pioneering effort where a simple modification to the spirometer enables the patient to breathe out through the nose only.

The terminology used in this paper for the three techniques which have been used for connecting the spirometer tube to the subject is as follows:

1. Oral spirometry - Using conventional mouthpiece and nose clip
2. Oronasal spirometry - Using mask over the nose and mouth
3. Nasal spirometry - Using mask over the nose only with the mouth closed

The purpose of the present study is to compare oronasal and nasal spirometry measurements in healthy individuals and establish normal values for nasal spirometry.

MATERIALS AND METHODS

Two sets of measurements were obtained from each subject. (1) A mask was placed over the nose and mouth and measurements done. This is referred to as oronasal spirometry. (2) In the same subjects, a smaller mask was placed over the nose and the measurement repeated with the mouth closed and the patient breathing through the nose. We have called this nasal spirometry since airflow is through the nasopharynx and nose. We believe that this method can be used in the diagnosis and assessment of nose–nasopharynx obstructions.

Study Participants

A total 600 healthy participants both male and female were recruited for this study. Subjects were divided into three groups based on age.
Group 1: 6–15 years.

Group 2: 16–35 years.

Group 3: 36–50 years.

In all groups, healthy non-athletes and non-smokers were selected. Subjects with common cold, asthma, those with nasal pathologies such as allergic rhinitis, excessive turbinate hypertrophy, and nasal polyposis, and those who would not cooperate were excluded from the study. This study was approved by the Institutional Human Ethical Committee (Ref: IHEC No. 015/01/2015/IEC/SU) of Saveetha Institute of Medical and Technical Science (SIMATS). Before implementing the procedure, detailed explanation of the test protocol was given and informed consent was obtained from each participant or parent.

Spirometer

RMS Helios 401 Spirometer, an electronic, hand-held device with the computerised program was used to assess lung function parameters. The subject breathes into a flow meter which is protected by a bacterial filter. Helios 401 uses an innovative digital turbine to deliver accurate inspiratory and expiratory measurements at low-to-high rates. The turbine is detachable and easy to disinfect. For this study, two masks were used in turn, one covering the mouth and nose and the other covering the nose only. During measurement, the appropriate mask was connected to the breathing tube of the instrument. The instrument records several parameters such as FVC, FEV1, FEV1/FVC%, forced expiratory time (FET), peak expiratory flow rate (PEFR), forced inspiratory flow at 50% of inspired volume during FVC test (FIF50%), forced expiratory flow at 50% of expired volume during FVC test (FEF50%), and peak inspiratory flow rate (PIFR) digitally in variable seconds and as percentages besides providing a computer recorded tracing.

Oronasal Spirometry

Instead of using mouthpiece as in conventional method, a face mask (No: 4/5 for adults and No. 3 for children) which covered both mouth and nose and fitted comfortably was selected for each participant. The subject was asked to practice normal and maximal breathing with the mask under supervision before the actual measurement. During measurement, the subject was asked to keep the mouth open all the time, breathe normally twice, then breathe out maximally, and follow it with a maximum inspiration. Each subject was asked to complete three trials, and the best one was selected for the study. At least 2–3 min rest was given between two successive trials.

Nasal Spirometry

Before starting the measurement, Otrivine nasal spray (Xylometazoline Hydrochloride 0.1% w/v, Zyma Healthcare) was used as a standard nasal decongestant. This was administered to the subject at a dose of two sprays (0.3 ml) to each nostril. A period of 20 min was then allowed for nasal decongestion to occur before measurement. Each subject held the mask (no: 3 or 2) tightly on the nose and was instructed to close his/her mouth firmly. During nasal spirometry, if mouth leakage was either reported by the subject or noticed by the research team, the test was discarded and repeated all over again. Measurement procedure was the same as for oronasal method.

Statistical Analysis

The analysis was carried out on Sigma plot 13 (Systat Software, USA). The results are presented as mean ± standard error. One-way analysis of variance (ANOVA) followed by Student–Newmen–Keuls method (multiple comparison procedures) was used to compare the lung parameters among different age groups in oral and nasal spirometry method. $P < 0.001$ was considered statistically significant.

RESULTS

Findings of the present study are depicted in Tables 1–3.

DISCUSSION

In nasal spirometry, air passes only through the nose–nasopharynx region unlike in conventional spirometry with mouthpiece and nose clip where air flows only through the mouth. It is possible that nasal spirometry may detect some aspect of nose–nasopharynx obstruction which may help in the assessment of patients with obstruction in this region. Since normal values for nasal spirometry do not exist, we have performed oronasal and nasal spirometry in 600 healthy subjects in three age groups.

Table 1: Spirometric parameters in oronasal and nasal spirometry among males and females (age 6–15 years)

Variables	Male		Female	
	Oronasal	Nasal	Oronasal	Nasal
FVC	1.38±0.01	1.15±0.02*	1.34±0.02	1.24±0.05^{ns}
FEV1	1.38±0.01	1.09±0.02*	1.25±0.02	1.16±0.05^{ns}
FEV1/FVC%	99.28±0.06	95.78±0.66*	96.03±0.70	95.88±0.73^{ns}
PEFR	3.12±0.02	1.72±0.04*	2.84±0.13	1.87±0.09*
FEF50%	2.41±0.02	1.61±0.04*	2.43±0.13	1.65±0.09*
FET	0.90±0.01	0.94±0.02^{ns}	1.16±0.04	1.08±0.04^{ns}
PIFR	1.53±0.02	0.88±0.02*	1.73±0.04	1.29±0.09*
FIF50%	1.49±0.02	1.06±0.01*	1.63±0.44	1.20±0.03*

Data expressed as mean±SE. FVC: Forced vital capacity, FEV1: Forced expiratory volume in first second, FEV1%: Percentage of FVC expired in the first second, PEFR: Peak expiratory flow rate, FEF50%: Forced expiratory flow at 50% of expired volume during FVC test, FET: Forced expiratory time, PIFR: Peak inspiratory flow rate, FIF50%: Forced inspiratory flow at 50% of inspired volume during FVC test. *Statistically significant difference from oral values (P<0.001). ^{ns}Statistically non-significant difference from oral values (P<0.001)

Table 2: Spirometric parameters in oral and nasal spirometry among males and females (age 16–35 years)

Variables	Male		Female	
	Oronasal	Nasal	Oronasal	Nasal
FVC	3.35±0.05	2.80±0.06*	2.37±0.04	1.80±0.04*
FEV1	3.06±0.04	2.59±0.04*	2.21±0.04	1.80±0.04*
FEV1/FVC%	95.48±0.48	92.36±0.96*	95.78±0.42	89.64±1.16*
PEFR	6.97±0.14	4.52±0.16*	4.28±0.09	3.21±0.07*
FEF50%	4.34±0.10	3.19±0.19*	3.30±0.07	2.30±0.08*
FET	1.11±0.04	1.34±0.04*	1.18±0.03	1.33±0.03*
PIFR	4.01±0.11	3.22±0.12*	2.31±0.07	1.41±0.07*
FIF50%	3.01±0.13	1.74±0.07*	2.14±0.07	1.44±0.06*

Data expressed as mean±SE. FVC: Forced vital capacity, FEV1: Forced expiratory volume in first second, FEV1%: Percentage of FVC expired in the first second, PEFR: Peak expiratory flow rate, FEF50%: Forced expiratory flow at 50% of expired volume during FVC test, FET: Forced expiratory time, PIFR: Peak inspiratory flow rate, FIF 50%: Forced inspiratory flow at 50% of inspired volume during FVC test. *Statistically significant difference from oral values (P<0.001). ^{ns}Statistically non-significant difference from oral values (P<0.001)

Table 3: Spirometric parameters in oral and nasal spirometry among males and females (age 36–50 years)

Variables	Male		Female	
	Oronasal	Nasal	Oronasal	Nasal
FVC	2.86±0.06	2.57±0.06*	2.30±0.04	2.37±0.05*
FEV1	2.74±0.05	2.37±0.05*	2.17±0.04	1.76±0.03*
FEV1/FVC%	89.77±0.51	93.48±0.55*	92.51±0.56	96.90±0.40*
PEFR	6.09±0.17	3.73±0.13*	4.05±0.08	2.54±0.09*
FEF50%	4.21±0.05	4.04±0.13*	3.06±0.05	2.50±0.05*
FET	1.58±0.49	1.44±0.04*	1.28±0.03	1.25±0.03^{ns}
PIFR	3.06±0.13	1.78±0.08*	2.08±0.08	1.82±0.06*
FIF50%	3.58±0.09	2.97±0.11*	1.99±0.07	1.60±0.06*

Data expressed as mean±SE. FVC: Forced vital capacity, FEV1: Forced expiratory volume in first second, FEV1%: Percentage of FVC expired in the first second, PEFR: Peak expiratory flow rate, FEF50%: Forced expiratory flow at 50% of expired volume during FVC test, FET: Forced expiratory time, PIFR: Peak inspiratory flow rate, FIF 50%: Forced inspiratory flow at 50% of inspired volume during FVC test. *Statistically significant difference from oral values (P<0.001). ^{ns}Statistically non-significant difference from oral values (P<0.001)

In oronasal spirometry, the subject breathes through the nose and mouth, while in conventional spirometry, breathing is through the mouth only. Since the oral pathway is used in both, and additionally, nasal pathway is used in oronasal spirometry, one feels that there should be no difference between the two sets of results. This view is supported by several studies which have shown that values obtained using the face mask are similar to those using the mouth piece and nose clip,[5] and in fact, this was the only method of measuring lung function in patients with muscular disorders affecting facial muscles.[6,7]

To validate our oronasal values, we have compared our values with some selected published values for FVC and FEV1. Arriving at normal values for these two parameters is complicated by their wide range and influence of age, sex, race, stature, and regular exercise. Racial variations exist between countries and even within countries. In India, there are differences between various regions; South Indian values for FVC are shown to be less than that of North Indians.[8] South Indian values are similar to those of Negroes, and European values multiplied by 0.87 can be used as South Indian norms.[9]

Based on these facts, three published normal values were selected, the subjects being South Indians, residents of Chennai, and Jamaican Negros. The fourth group was our 200 subjects in the age group if 16–35. The final group is obtained from nomograms for 30-year-old Europeans of average height. A comparison of mean values for FVC and FEV1 for these five groups is shown in Table 4.

Except for values calculated from the standard European measurements of 30-year olds multiplied by 0.87 given in the last column, the three results obtained by researchers using oral spirometry are similar, and they also match oronasal results of the present study. They are also analogous to adult Chinese[13] and Indian[14] studies which were carried out by conventional oral spirometry. Within similar groups, our oronasal values are seen to be similar to published oral values.

Since we have measured both oronasal and nasal parameters in each subject, it provides us with a unique opportunity to eliminate the problem of large normal range in one stroke. Finding the difference between oronasal and nasal values for each parameter would improve the accuracy of interpretation manifold.

The parameters measured in the present study are FVC, forced expiratory volume in the first second (FEV1), percentage of FVC expired in the first second (FEV1%), PEFR, FEF50%, FET, PIFR, and FIF50%.

In the age group of 16–35 years, all the parameters are significantly less in nasal spirometry when compared to oronasal spirometry (Table 2). In the 36–50 years group, the results were similar except for FET which did not differ significantly in females (Table 3). In the age group of 6–15 years, differences in FET were not significant in both the sexes. In males, FVC, FEV1, and FEV1% were significantly less for nasal spirometry, but in females, there was no significant difference (Table 1).

Only one study is reported where a slightly modified form of nasal spirometry was carried out. In this, a mask was used over the nose and mouth, and the subjects were instructed to close their mouth tightly and breathe out through their

Table 4: Published mean values for FVC and FEV1 compared to the present study

Authors	Kamat *et al.*[10]	Vijayan *et al.*[11]	Osherwitz *et al.*[12]	Present study (oronasal value)	Cotes[9]
Ethnicity	**South Indian**	**Chennai**	**Negros**	**Chennai**	**30-year-old Europeans of average stature×0.87**
Number	1247	247	110	200	
Age group	15–55	15–40	20–65	16–35	30
FVC (l)					
Male	3.34	3.53	3.72	3.35	3.95
Female	2.34	2.37		2.37	3.30
FEV_1(l)					
Male	2.84	3.02	2.84	3.06	3.20
Female	1.89	2.08		2.21	2.61

nose. At the same time, oral values with mouthpiece and nose clip were also obtained.In this study, all nasal values were less than oral values except for slow VC in which nasal measurement was higher.[15]

The reason for most of the parameters being less in nasal spirometry is likely to be the more devious and narrower nose–nasopharyngeal pathway when compared to the double pathway (nose and mouth) in oronasal spirometry. Conceptually, this difference could affect most of the parameters but how it affects FVC is difficult to understand since the point of maximum inspiration and maximum expiration should not differ in the same person during the two types of measurement. This situation may become clearer if slow vital capacity was also measured in addition to FVC. Differences in FET were found, but are not consistent. FET could become significant is cases of obstruction; this has not been mentioned previously. The male-female differences in adults are not so apparent in children. This could be due to the incomplete mid-face development which could influence the size of nasopharynx at the time of the study.

The strength of our study is the simplicity of measurement. In addition, it is a new attempt to assess nasopharyngeal obstruction. Pre- and post-operative measurements can be made in patients with adenoids. Since the instrument is a portable one, measurements can be made with the patient in different positions too. This may be advantageous in patients with OSA. With small modification, airflow through each nostril may be measured; this could be helpful in patients with DNS.

There are some inherent weaknesses too. The main one is the prevention of leakage around the mask. Patient cooperation is also essential as in all spirometric measurements.

CONCLUSION

A new method of assessing airflow through the nose–nasopharynx named nasal spirometry is introduced. To establish normal values, simultaneous measurements by oronasal spirometry which compares with standard spirometry were also made in 600 normal subjects in three age groups.

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How to cite this article: Devi RG, Sethu G. Establishing norms for nasal spirometry. Natl J Physiol Pharm Pharmacol 2018;8(8):1188-1193.

Source of Support: Nil, **Conflict of Interest:** None declared.