Is Nasal Cavity Geometry Associated With Body Mass Index, Height And Weight?

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Abstract It has been reported that nasal airflow rate and pressure increased with increasing body mass index (BMI). The purpose of this study is to determine if with an increased BMI, the nasal cavity geometry as measured by acoustic rhinometry (AR) increased in healthy adult Singaporeans. This is a population based study. Seventy-three healthy volunteers, 44 males and 29 females aged 18–64 years (mean 34.9 years) were selected. Their BMI was calculated from height and weight measurements. AR was used to measure the minimum cross-sectional area 1–5 cm from the nostril, cross-sectional area at 3.3 and 4 cm and volume 1–5 cm from the nostril of the nasal cavity. There was no statistically significant correlation between BMI, height and weight with all AR measurements. Our study demonstrates that nasal cavity geometry is not affected by increasing BMI, as well as height and weight individually, of healthy adult Singaporeans. Our study indicates that subject with obesity is potentially facing a long-term physiological risk for insufficient air-exchange, or burden of increasing the respiratory rate and/or volume of each breath.

Keywords Acoustic rhinometry · Body mass index · Body height · Body weight · Nasal cavity

Introduction

Findings by Crouse and Laine-Alava suggested that adults with high relative body mass have an increased demand for

oxygen and thus may have to breathe with higher frequency or more larger volumes during each inspiration [1]. In addition, an increased relative body mass index (BMI) is related to increased oral and nasal pressures, as well as an increased nasal airflow rate. They feel that since the higher airflow rates were clearly evidenced in subjects with high BMI, it suggested that there might also be a correlation between BMI and nasal airway size and resistance to inspiratory airflow.

BMI is the weight-height ratio. It correlates better with body fat than any other indicator of height and weight [2]. Acoustic rhinometry (AR) is a non-invasive, rapid and highly reproducible method to measure cross-sectional areas (CSAs) and nasal volumes and it requires minimal co-operation from the patient [3–6]. The advantage of this technique is that it displays the CSAs and volumes in a two dimensional graphic display of the nasal cavity.

Two previous studies carried out in Sweden and Finland demonstrated weak or no correlation between BMI and nasal cavity geometry in adults [5, 7]. Such a study has not been reported in the Asian population, which is important in standardization of reference values for AR measurements. The aim of this study was to investigate the relationship between nasal cavity geometry as measured by AR and body height, body weight and BMI in adult healthy Singaporeans. We also attempted to determine standardized values for AR measurement in our local population.

Materials and Methods

Study Subjects

In a national rhinitis survey study, a total of 268 volunteers were randomly called to attend a rhinologic examination in

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the ENT out-patient clinic at the National University Hospital (NUH) of Singapore. Subjects included were those without any nasal symptoms and no history of taking any medication for at least 1 month before entering the study. Individuals were excluded if there was a history of rhinitis/sinusitis or nasal structure malformations. The group of 73 volunteers selected was made up of 44 males and 29 females between 18 and 64 years of age (mean 34.9 years). The study was conducted over a period of 2 months. Each subject was required to visit the clinic only once. They gave their informed consent to the study. Approval to conduct this study was granted by the institutional review board of The National Medical Research Council (NMRC) of Singapore.

BMI

For each subject standing body height and body weight was measured. BMI was then calculated using the following formula: $BMI = \text{weight in kilograms}/(\text{height in meters})^2$ [2].

AR Measurement

AR measurements were performed according to the standard procedure as described in our previous reports using the SRE 2100 (Rhinometrics A/S, Lynge, Denmark) [8, 9]. Briefly all subjects were acclimatized for 20 min prior to the test. They sat upright in an armchair, with the head properly supported, and breathed quietly through the mouth. Room temperature was kept constant by means of central air-conditioning, and noise levels were maintained according to the manufacturer's requirement. The following measurements were taken on both sides of the nasal cavity as described in previous studies [8–11].

- CSA-3.3: CSA at the distance of 3.3 cm from the nostril.
- CSA-4.0: CSA at the distance of 4.0 cm from the nostril.
- MCA: Minimum cross-sectional area between 1 and 5 cm from the nostril
- *mMCA*: Mean minimum cross sectional area. This is the average of the right and left MCA
- V: Nasal volume from 1 to 5 cm from the nostril. Total nasal volume (tV) was calculated as the sum of the right and left V.

Statistical Analysis

All data were expressed as mean and median with minimum and maximum values. Pearson and Spearman correlations were used to investigate the association between BMI, body height and body weight and AR measurements.

Correlation between the different AR measurements were also tested. A *P*-value of less than 0.05 was considered statistically significant. All statistical analyses were performed using SPSS (SPSS Inc. Chicago, Illinois) statistical package (version 10.0) for windows.

Results

All study subjects completed this study. Table 1 summarizes the age, weight, height and BMI characteristics of the study population. BMI distribution is given in Table 2. There was no one in the obese class III category (BMI over 40 kg/m²) [12].

Values of different AR measurements are given in Table 3. There is a significant correlation (*P* < 0.001) among all AR measurements.

Age range of the study population was 18–64 years old with a mean ($\pm$ standard error) of 34.9 ± 1.4 years. However none of the AR measurements correlated significantly with age. Measurements of BMI, body height, body weight showed no statistically significant correlation with any AR measurements.

Table 1 Characteristics of study subjects

	Mean $\pm$ SD	Median	Minimum	Maximum
Female				
Age (year)	36.6 $\pm$ 10.9	37	18	59
Weight (kg)	57.9 $\pm$ 11.8	55.0	38.0	88.0
Height (m)	1.57 $\pm$ 6.4	1.56	1.44	1.67
BMI (kg/m ²)	23.9 $\pm$ 4.9	22.7	15.6	37.6
Male				
Age (year)	33.5 $\pm$ 11.7	30	22	64
Weight (kg)	66.9 $\pm$ 9.3	65.5	38.0	86.0
Height (m)	1.71 $\pm$ 7.3	1.72	1.50	1.88
BMI (kg/m ²)	22.7 $\pm$ 3.3	22.7	13.2	30.5

BMI body mass index

Table 2 Body mass index distribution of study population

BMI (kg/m ²)	WHO	Study (n)
<18.5	Underweight	4
18.5–24.99	Normal range	50
$\geq$ 25.00	Overweight	19
25.0–29.9	Preobese	15
30.0–34.99	Obese class I	3
35.0–39.9	Obese class II	1
$\geq$ 40.0	Obese Class III	0

BMI body mass index, WHO World Health Organization [12]

Table 3 Acoustic rhinometric measurements

	Right $\pm$ SE	Left $\pm$ SE	Mean $\pm$ SE	Total $\pm$ SE
CSA-3.3 (cm ²)	1.24 $\pm$ 0.07	1.30 $\pm$ 0.06	NA	NA
CSA-4.0 (cm ²)	1.76 $\pm$ 0.12	1.68 $\pm$ 0.08	NA	NA
MCA (cm ²)	0.74 $\pm$ 0.04	0.74 $\pm$ 0.03	0.74 $\pm$ 0.03	NA
V (cm ³)	5.69 $\pm$ 0.20	5.60 $\pm$ 0.17	NA	11.3 $\pm$ 0.3

CSA cross sectional area, MCA minimum cross sectional area, V volume of nasal cavity 1–5 cm from the nostril, NA not applicable

Discussion

After being introduced in 1989 by Hilberg et al. [4] more than 200 publications have been published dealing on different aspects of AR [10]. Since then the standardization for AR measurements in the “normal nose” as compared to different types of structural and mucosal abnormalities are important. The anatomy of a normal human nose varies with many anatomical and physiological factors such as development, age, ethnicity, nasal cycle and posture. The effect of BMI, height and weight could also be a variable and warrant study.

A strict selection criteria was abided to select 73 subjects out of an initial 268 volunteers so that each subject were subjectively and objectively healthy in both nasal function and structure. Furthermore decongestants were not used during measurement, as it would have changed the normal mucosa turgidity of the nasal cavities, thereby invalidating the measurements as indicators of normal status in healthy noses [7]. Additionally each subject went through 20 min of acclimatization to reduce the mucosal variability during measurement [13].

AR measures the cross sectional area and volume of the nasal cavity at varying distances from the nostril. The normal values of mMCA in this study (0.74 ± 0.03 cm²) correlates well with our previous study (0.75 ± 0.02 cm²) that was performed in healthy adult Singaporean Chinese, Malays and Indians [8]. The same study also demonstrated that there was no significant difference of AR measurements in these three races. Each measurement was taken by the same equipment at different times and by different operators. The similarity of values proves the accuracy of AR measurement and that it can be used as a reference for normal values in our population.

BMI is calculated as a ratio between weight and height. It is an indicator of body mass and is a reliable indicator of body fat [2]. The mean BMI of this study population was 23.1 kg/m² (median of 22.7 kg/m²), which is close to an adult ideal BMI as recommended by World Health Organization (WHO) [12]. The age, weight, height and BMI distribution of our study population corresponded well with a cross-sectional population study carried out by Deurenberg-Yap et al. based on 4723 adult Singaporeans [14]. It

indicates that our study population was representative of the Singaporean population. There were no subjects with a BMI over 40 kg/m² (Obesity class III) as defined by WHO [12], since they all come from a randomized rhinitis survey study.

Individuals with a higher body mass require more oxygen, which will be physiologically compensated by increasing the respiratory rate and/or volume of each breath. There are only a few studies investigating the relationship between BMI (including height and weight) and nasal cavity geometry, airflow rate and resistance [1, 7, 15]. According to our study and other published data, it seems neither resistance nor nasal cavity size changed with increasing BMI [7, 15]. Whether this lack of correlation has any role on illnesses associated with increased body mass could be a matter of interest. However we did not have any patients in our study with morbid obesity (Obesity class III, BMI > 40 kg/m²). Further studies to illustrate the effect of a very high BMI on nasal cavity geometry and respiratory physiology are needed.

Key Messages

The present study demonstrates that there is no correlation between BMI, body height and weight, and the nasal cavity geometry as measured by AR. Data from this study can be used to standardize reference values for normal AR measurements in the Asian population. Objective measurements of nasal cavity geometry and ventilation could be important in the investigation of respiratory physiology and pathophysiology.

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