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Does Nasal Obstruction Mean That the Nose Is Obstructed?

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Objectives/Hypothesis: It is still a matter of controversy to what extent the sense of nasal obstruction is associated with objective measures for nasal space and airflow. Knowledge about this is important in the evaluation of nasal complaints and the planning of its treatment. In this study, we evaluated the relationship between subjective nasal obstruction and the corresponding anatomic and physiological nasal parameters using acoustic rhinometry (AR) and peak nasal inspiratory flow (PNIF).

Study Design: Two thousand five hundred twenty-three consecutive patients were included in this cross-sectional study. Eligible subjects were adults referred to the Ear, Nose, and Throat Department, Sørlandet Hospital, Kristiansand, Norway, for evaluation of chronic nasal or sleep related complaints.

Methods: Subjects underwent AR and nasal flow measurements. Subjective grading of nasal obstruction was obtained by a nasal obstruction visual analogue scale. Associations between nasal obstruction visual analogue scale scores, AR, and PNIF were assessed using multiple linear regression, adjusting for age, gender, body mass index, and asthma, allergy, and smoking history.

Results: The sense of nasal obstruction was associated with nasal cavity volumes in both anterior and middle segments of the nasal cavities, with minimal cross-sectional areas in middle segments and for the nasal cavity as a whole, and with PNIF. Associations with minimal cross-sectional areas in anterior segments did not reach significance.

Conclusions: The present study demonstrates highly significant associations between the subjective sensation of nasal obstruction and corresponding measures for nasal cavity volume, area, and airflow. We conclude that AR and PNIF are valuable objective instruments for evaluation of subjective nasal obstruction.

Key Words: Nasal obstruction, acoustic rhinometry, peak nasal inspiratory flow, visual analogue scale, symptoms, association.

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INTRODUCTION

Nasal obstruction is a major diagnostic challenge for the physician because of its frequency and variety of etiologies. It is a subjective parameter, defined as the feeling of impaired nasal breathing, and represents a key symptom that causes patients to seek medical attention. Inconsistency between symptoms of nasal obstruction and the appearances of the nasal cavities is not uncommon and therefore objective criteria are required for accurate diagnosis, staging of pathology, and assessment of therapeutic results. Two commonly used methods for assessment of the nasal airway are acoustic rhinometry (AR) and peak nasal inspiratory flow (PNIF). For evaluating patients' subjective experience of nasal obstruction visual analogue scales (NO-VAS) are commonly used. However, the relationship between subjective and objective measures of nasal obstruction remains controversial. Although several studies have addressed this problem, consensus is lacking.[1,2]

The aim of the present study was to investigate the relationship between the subjective sensation of nasal obstruction and the corresponding objective parameters for nasal space and airflow.

MATERIALS AND METHODS

Subjects

A cross-sectional study was conducted on 2,523 consecutive adult patients, mainly white, referred to the Ear, Nose, and Throat Department, Sørlandet Hospital Kristiansand, Norway, for evaluation of sleep related disorders (snoring, sleep apnea) or chronic nasal complaints, in the period 2001–2007. All referred patients were included, also counting patients with prior nasal surgery and those taking nasal medications. The subjects underwent AR and PNIF within 15 minutes. Questionnaires and height and weight measurements were all obtained on the same day, before the nasal recordings.

Acoustic Rhinometry

AR noninvasively measures nasal airway cross-sectional area as a function of longitudinal distance along the nasal passageway

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following the path of an acoustic pulse. Nasal passage volumes can be calculated from contiguous cross-sectional values.[3] The method is appropriate for anatomic assessment of the nasal airway and has been independently validated against other anatomic measures.[4] An impulse acoustic rhinometer (RhinoMetrics SRE2100, Rhinoscan version 2.5, built 3.2.5.0; Interacoustics, Minneapolis, MN) was handled by three trained operators throughout the study. Recordings were performed in accordance with published protocols, following recommendations for standard operating procedures.[5] Three curves from both nasal cavities were averaged to get a mean curve for each side. To account for variations between nostrils due to the nasal cycle, average values from the left and right side were calculated. Recordings were obtained from anterior and middle segments of the nasal cavities. The anterior segment of 0 to 3 cm into the nasal cavity represents the nasal vestibulum and valve area, containing only limited congestive capacity. The middle segment of 3 to 5.2 cm into the nasal cavity represents the turbinated region of the nasal cavity where the mucosa has a vast congestive capacity. Recordings from the posterior nasal cavity were not obtained because they are not considered reliable due to loss of acoustic energy and consequent underestimation distal to constrictions.[3,6] The following measures were recorded: minimum cross-sectional area (MCA) in cm^2 between 0 and 3 cm (MCA1), 3 to 5.2 cm (MCA2), and 0 to 5.2 cm (MCA3) behind the nostril; nasal cavity volumes (NCV) in cm^3 between 0 and 3 cm (NCV1) and 3 to 5.2 cm (NCV2) behind the nostril.

Peak Nasal Inspiratory Flow

PNIF is a noninvasive easy to perform method commonly used to assess nasal patency. It is a physiological measure indicating the peak nasal airflow in liters per minute achieved during forced inspiration. The method is suggested to be reliable for assessment of nasal patency as it has proved to be reproducible and in concordance with other objective tests.[7,8] In the present study, a portable peak flow meter (In-check DIAL; Clement Clarke International, Harlow, Essex, UK) was used. Patients were carefully instructed in a standardized technique using the same nasal flow meter equipped with facemasks. Three satisfactory maximal inspirations were obtained with the patient in an upright position. The mean value was calculated for subsequent analysis. Maximum flow registration was set to 120 L/min. Peak flows exceeding 120 L/min were recorded as 120 L/min.

Subjective Assessment

VAS is a quantitative measure validated in many diseases. NO-VAS is a widely used instrument for evaluation of subjective nasal obstruction.[2] In the present study, subjects were asked to grade their present degree of nasal obstruction on a scale with anchor 0 indicating no symptoms ("fully open") and anchor 100 indicating maximum symptoms ("totally obstructed"). NO-VAS was categorized into three groups; mild, moderate, and severe (Table I), based on the total severity VAS for chronic rhinosinusitis as described in EP3OS 2007.[9]

Possible Confounders

On enrollment, each subject completed a short questionnaire that included questions about age, gender, smoking habits, and presence of allergy and asthma. Height and weight were measured at the time of enrollment, using the same measuring device for each subject. Body mass index was calculated as kilograms per square meter. In addition, type of planned intervention (continuous positive airway pressure, septoplasty, turbinectomy, uvulo-palato-plastic, functional endoscopic sinus surgery) was recorded.

Statistics

Data were described with mean and standard deviation or median with range when not normally distributed. The crude differences between the subjective measures divided into groups based on NO-VAS were studied using analysis of variance table and *f* tests. To uncover adjusted relations between the subjective and objective measurement, several linear regression models were fitted. In addition, both the subjective and objective measurements were standardized (their mean was subtracted and the values were divided by standard deviation) so that the results could be interpreted as % changes. Because of a very large sample size the model fit was very good. P values $<.05$ were considered statistically significant. All analyses were performed with SPSS ver.13 (SPSS, Inc., Chicago, IL).

RESULTS

The sample population was middle aged, slightly overweight and with a preponderance of males and smokers (Table II). Nasal recordings are presented in Table III. The mean MCA3 at baseline (0.43 cm^2) was slightly below mean values from normative data.[5] Mean PNIF (83 L/min) was not directly comparable with normative data because values above 120 L/min were recorded as 120 L/min, thereby lowering the mean. In the majority of subjects the MCA for the whole nasal airway (MCA3) was located in the valve region (MCA1). However in 16.5% of the cases it was located more posteriorly (MCA2). This is most likely due to hypertrophy of the anterior part of the inferior turbinate.[10] The unadjusted associations between NO-VAS in three categories and the objective measures are illustrated in Figure 1. The difference between the mean value of the objective measure in each of the three NO-VAS categories were statistically significant for MCA2 ($P < .001$), MCA3 ($P < .001$), NCV1 ($P < .001$), NCV2 ($P = .002$) and PNIF ($P < .001$), and nonsignificant for MCA1 ($P = .09$). When adjusted for possible confounders five of six tested objective measures were highly associated ($P < .001$) with subjective nasal obstruction (Table IV). All of the associations

TABLE I.
NO-VAS in 3 Categories.

	Category 1 Mild	Category 2 Moderate	Category 3 Severe
NO-VAS	0–30	31–70	71–100

NO-VAS = nasal obstruction visual analogue scale.

TABLE II.
Sample Characteristics (n = 2523).

Patient Demographics	n (%)	Median	Range
Age (yrs)		46	16–87
BMI (kg/m^2)		26.6	15–85
Gender			
Male	1761 (70)		
Female	762 (30)		
Asthma	278 (11)		
Allergy	732 (29)		
Smoking	833 (33)		

BMI = body mass index.

TABLE III.
Nasal Recordings.

Variable	Mean	SD
Acoustic rhinometry		
MCA1	0.45	0.14
MCA2	0.70	0.30
MCA3	0.43	0.14
NCV1	2.10	0.43
NCV2	3.33	1.15
PNIF, mean	83	31
NO-VAS	47	27

SD = standard deviation; MCA1 = minimal cross-sectional area 0–3 cm behind the nostril (cm^2); MCA2 = minimal cross-sectional area 3–5.2 cm behind the nostril (cm^2); MCA3 = minimum cross-sectional area 0–5.2 cm behind the nostril (cm^2); NCV1 = nasal cavity volume 0–3 cm behind the nostril (cm^3); NCV2 = nasal cavity volume 3–5.2 cm behind the nostril (cm^3); PNIF = peak nasal inspiratory flow (L/min); NO-VAS = nasal obstruction visual analogue scale.

were in the expected negative direction: a negative estimate of beta ([β]) means that e.g., a reduction in NCV indicating narrower nasal cavities was associated with an increase in NO-VAS indicating more subjective complaints. The association between NO-VAS and MCA2 ([β] = −15.8; 95% CI: −19.6 to −12.1) and MCA3 ([β] = −25.6; 95% CI: −34.9 to −16.3) indicated that a change in MCA2 and MCA3 of 1 cm^2 corresponded to a 15.8 and 25.6 point change in the opposite direction in NO-VAS. Similarly the association between NO-VAS and NCV1 ([β] = −12.8; 95% CI: −15.6 to −10.1) and NCV2 ([β] = −1.9; 95% CI: −2.9 to −0.9) indicated that a decline in NCV1 and NCV2 of 1 cm^3 corresponded to an increase in NO-VAS of 12.8 and 1.9 points, respectively. The adjusted association between NO-VAS and PNIF indicated that a change in PNIF ([β] = −0.17; 95% CI: −0.2 to −0.13) of 1 L/min caused a change of 0.17 points in the opposite direction in NO-VAS. Therefore, within the range of our registrations of PNIF (120 units) the NO-VAS was affected by 0 to 20.4 points. When dividing PNIF into four categories as shown in Table IV, associations were similar. The adjusted association between MCA1 and NO-VAS did not reach significance. To better quantify the strength of the relations among the objective and subjective measures, we applied linear regression with standardized values, which expressed the differences in percent changes (Table V). Modeled as described above a 10% change in MCA2 resulted in a 2% change ([β] = −0.20; 95% CI: −0.24 to −0.16) in NO-VAS in the opposite direction. A 10% change in MCA3 resulted in a 1.2% change ([β] = −0.12; 95% CI: −0.16 to −0.07) in NO-VAS in the opposite direction. Similarly a 10% change in NCV1 resulted in a 2.3% change ([β] = −0.23; 95% CI: −0.28 to −0.19) in NO-VAS in the opposite direction. The relationship between NCV2 and NO-VAS was somewhat weaker; a 10% change in NCV2 resulted in a 0.5% change ([β] = −0.05; 95% CI: −0.09 to −0.01) in NO-VAS in the opposite direction. Finally a 10% change in PNIF resulted in a 1.9% change ([β] = −0.19; 95% CI: −0.23 to −0.15) in NO-VAS in the opposite direction. The relationship between NO-VAS and the dependant variable was adjusted for possible confounders. Age, smoking status, body mass index, and asthma were significant confounders for all the associations and adjusted for. Additionally, gender and allergy were significant confounders for associations between NO-VAS and MCA3 and gender was a significant confounder for the association between NO-VAS and NCV1. The results remained the same even when adjusted for type of planned intervention.

DISCUSSION

Nasal obstruction is difficult to quantify by subjective and clinical measures alone and objective methods for assessment and staging of pathology should be applied. But does objective severity of nasal obstruction correspond with subjective assessment of obstruction impact? In the present study, we found a highly significant association between NO-VAS and five of six objective measures of nasal obstruction, adjusting for a large number of possible confounders. A 10% change in the objective parameter resulted in a change in NO-VAS of 0.5% to 2.3%. These results confirm the strong unadjusted inverse relationship we initially found between NO-VAS in three categories and five of six objective measures. We, therefore, have convincing evidence that the obtained objective measures are relevant markers for subjective nasal obstruction.

Based on our results it seems that the sensation of nasal obstruction is associated with the MCA for the nasal airway as a whole, MCA3. This indicates that the narrowest point of the nasal passage, the functional nasal valve, is an important determinant for subjective nasal obstruction. The lack of association between MCA1 and NO-VAS can be explained by the fact that the functional valve area was located in the middle segment of the nasal cavity in a significant number of subjects. Subjective nasal obstruction was also related to NCV in both anterior and middle segments of the nasal cavity. This indicates that mucosal congestion could play a significant role in the symptom complex. Further supporting this hypothesis is the fact that the turbinated region, despite having a relatively large cross-sectional area compared with the nasal valve, also seems to be a determinant for subjective nasal obstruction. Accordingly, not only high resistance areas in the nasal cavity are of relevance and conditions of the nasal mucosa such as congestion and inflammation could be of importance (to be published). Finally our study showed that PNIF performance was associated with subjective nasal obstruction, indicating a link between nasal flow properties and symptoms, which is in line with previous studies.[11]

Despite statistically significant associations between several objective and subjective measures of nasal obstruction, the correlation coefficients remained relatively low (r^2 = 0.13–0.35). The objective assessment of structural and functional measures therefore did not fully predict the patient's subjective perception of nasal obstruction. However, correlations as a way of expressing an association between a pair of variables can be very misleading, especially when data have a wide range of values because a wide range inflates the value of correlation. In

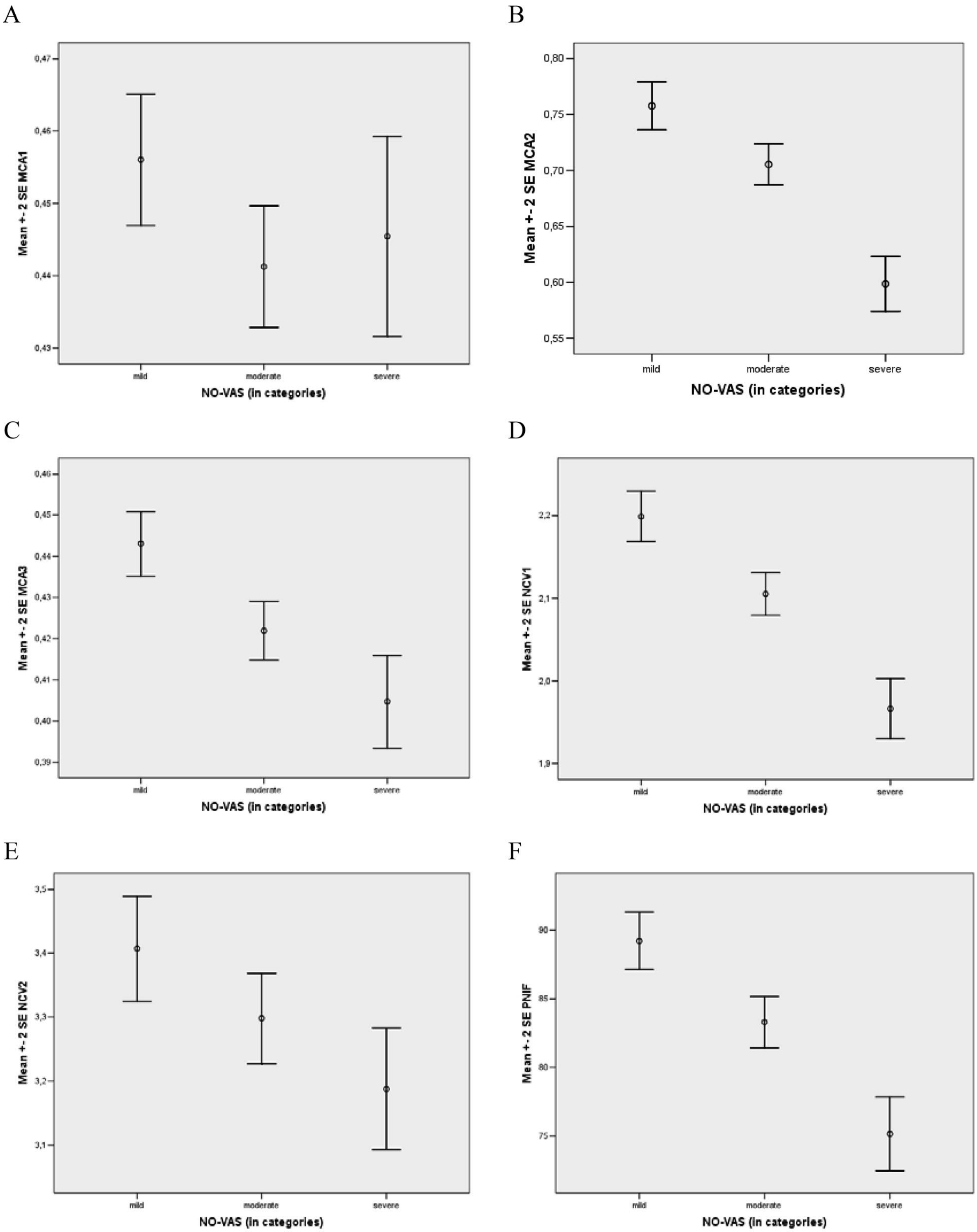

Fig. 1. Unadjusted associations between objective measures divided into the three nasal obstruction visual analogue scales (NO-VAS) categories. (A–C) Relationship between NO-VAS in three categories and minimal cross-sectional area (MCA) in cm^2. (A) 0 to 3 cm behind the nostril (MCA1), (B) 3 to 5.2 cm behind the nostril (MCA2), and (C) 0 to 5.2 cm behind the nostril (MCA3). (D–E) Relationship between NO-VAS in three categories and nasal cavity volume (NCV) in cm^3. (D) 0 to 3 cm behind the nostril (NCV1) and (E) 3 to 5.2 cm behind the nostril. (F) Relationship between NO-VAS in three categories and peak nasal inspiratory flow (PNIF) in liter per minute. There is an inverse association between NO-VAS and five of six objective measures, suggesting that smaller nasal cavities (MCA and NCV) and lower nasal airflow (PNIF) are related to greater symptoms of nasal obstruction. There is no significant association between MCA1 and NO-VAS (P = .09).

TABLE IV.
Multiple Linear Regression.

	[β]	95% CI	P
MCA1	−5.3	−13.7 to 3.0	.2
MCA2	−15.8	−19.6 to −12.1	<.001
MCA3	−25.6	−34.9 to −16.3	<.001
NCV1	−12.8	−15.6 to −10.1	<.001
NCV2	−1.9	−2.9 to −0.9	<.001
PNIF*	−4.0	−4.9 to −3.0	<.001

*Four categories of PNIF: (1) 120 L/min, (2) 90–119 L/min, (3) 60–89 L/min, (4) 0–59 L/min.

Estimates adjusted for age, gender, BMI, smoking status, allergy, and asthma.

CI = confidence interval; MCA1 = minimal cross-sectional area 0–3 cm behind the nostril (cm^2); MCA2 = minimal cross-sectional area 3–5.2 cm behind the nostril (cm^2); MCA3 = minimum cross-sectional area 0–5.2 cm behind the nostril (cm^2); NCV1 = nasal cavity volume 0–3 cm behind the nostril (cm^3); NCV2 = nasal cavity volume 3–5.2 cm behind the nostril (cm^3); PNIF = peak nasal inspiratory flow (L/min); BMI = body mass index.

addition, correlations are just crude estimates and cannot be adjusted for possible confounding.[12] The feeling of nasal obstruction has different etiologies and depends on more factors than nasal cavity dimensions and flows alone, e.g., pressure receptors, thermal receptors, pain receptors, secretions, and other. Accordingly, it is not justified to describe nasal obstruction by only a few variables like nasal space and airflow alone. Our findings, however, do emphasize that subjective nasal obstruction is often a marker for pathology and that AR and PNIF are useful instruments in diagnostic evaluation.

The study was based on a selected population; patients were evaluated for sleep related disorders or chronic nasal complaints. This has obvious limitations in terms of comparability to the normal population. Our sample population is likely to differ from the general population in nasal anatomy, physiology, and subjective report. This selection could, in part, be reflected in the male-to-female ratio, which showed a preponderance of male gender due to a large number of male subjects with sleep apnea and snoring in the cohort. In addition, smokers were overrepresented, suggesting a pooling of symptoms among smokers. However, the wide range of all the nasal measures, including the subjective rating indicates that our population was heterogeneous with respect to the nasal airway, with both extremes represented. This heterogeneity increases the power to detect associations and improves comparability. Differences in rhinologic diagnoses within the study population may have influenced the recordings. However, patients were not selected on the basis of rhinoscopy, because we wanted to eliminate the subjective element in the rhinoscopic evaluation, especially concerning the size of the turbinate and the degree of septal deviation. Yet, the results remained the same even when adjusted for type of intervention. Asthma and allergy are important confounders because of a high association between asthma, allergy and rhinitis and thus potential nasal obstruction. Furthermore, respiratory comorbidity could potentially affect the PNIF measurements by limiting the inspiratory effort.[13] Because asthma and allergy were self-reported in the present study, limitations are applicable to interpretation and extrapolation of the present results. However, the 10.7% prevalence of self-reported asthma in our study agrees well with reported prevalence.[14] The prevalence of allergy was 29%, which is only slightly above the prevalence in the region.[15] Another limitation is the lack of distinctions between asthma and COPD. Seasonal variation in pollination of different types was not controlled for in the study. However, because of the large sample size and the time frame of the study the potential confounding effects are likely to be diminished.

AR and PNIF measure different aspects of nasal patency namely structure and flow. Both techniques are highly variable, and for PNIF highly effort-dependant. Their reliability depends on optimal cooperation from the subject, correct instructions from the investigator, and standardized techniques. Close attention was paid to these elements. There are obvious limitations with VAS. Nevertheless, the method has been established as valid and reliable in a range of clinical and research applications. Simple VAS appears appropriate, especially when it is used in conjunction with other instruments like AR and PNIF, reflecting the multidimensionality of the sense of nasal obstruction.

To our knowledge, the present study is based on the largest sample size published to date, being several times larger than sample populations in similar studies. All subjective and objective recordings were performed in a controlled environment using modern equipment and trained personal, and estimates were adjusted for numerous confounders. Therefore, conclusions are regarded as strong. We have shown that there is a highly significant association between the severity of current symptoms of nasal obstruction and objective measures of PNIF and AR. Investigational instruments for nasal obstruction should preferably include components from anatomic, physiological, and subjective measures, and we want to emphasize the role of PNIF and AR as they are both quick and simple measures of objective nasal patency.

TABLE V.
Linear Regression Analysis with Centered Values.

	[β]	95% CI	P
MCA1	−0.15	−0.06 to 0.03	.472
MCA2*	−0.20	−0.24 to −0.16	<.001
MCA3*	−0.12	−0.16 to −0.07	<.001
NCV1†	−0.23	−0.28 to −0.19	<.001
NCV2*	−0.05	−0.09 to −0.01	<.001
PNIF‡	−0.19	−0.23 to −0.15	<.001

*Estimates adjusted for age, gender, BMI, smoking status, allergy, and asthma.

†Estimates adjusted for age, gender, and BMI.

‡Estimates adjusted for age, BMI, smoking status, allergy, and asthma.

CI = confidence interval; MCA1 = minimal cross-sectional area 0–3 cm behind the nostril (cm^2); MCA2 = minimal cross-sectional area 3–5.2 cm behind the nostril (cm^2); MCA3 = minimum cross-sectional area 0–5.2 cm behind the nostril (cm^2); NCV1 = nasal cavity volume 0–3 cm behind the nostril (cm^3); NCV2 = nasal cavity volume 3–5.2 cm behind the nostril (cm^3); PNIF = peak nasal inspiratory flow (L/min); BMI = body mass index.

CONCLUSIONS

The present study indicates that there are highly significant associations between the subjective sensation of nasal obstruction and the corresponding measures for area, space, and airflow. We conclude that AR and PNIF are valuable objective investigational instruments for evaluation of subjective nasal obstruction.

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