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ASSOCIATION OF DEVIATED NASAL SEPTUM SEVERITY WITH NASAL OBSTRUCTION SYMPTOM EVALUATION SCORE AND OBJECTIVE NASAL AIRFLOW PARAMETERS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Deviated nasal septum is a common structural cause of nasal obstruction. Anatomical severity does not always correspond to perceived obstruction because symptoms may also be influenced by mucosal congestion, turbinate hypertrophy, nasal valve function and individual airflow perception. Combining a validated symptom score with objective nasal airflow measurements may provide a more comprehensive assessment of functional obstruction. **Aim:** To assess the association of deviated nasal septum severity with the Nasal Obstruction Symptom Evaluation score and objective nasal airflow parameters among adults with nasal obstruction.

Materials and Methods: This hospital-based analytical cross-sectional study included 120 adults with symptomatic DNS. Septal deviation was assessed through anterior rhinoscopy and diagnostic nasal endoscopy and categorized as mild, moderate or severe. Subjective obstruction was evaluated using the validated five-item NOSE scale. Peak nasal inspiratory flow, total nasal airway resistance, minimum cross-sectional area and nasal cavity volume were measured before and after topical decongestion using PNIF, active anterior rhinomanometry and acoustic rhinometry. Group differences were analysed using one-way analysis of variance, Kruskal-Wallis and chi-square tests. Correlations were assessed using Spearman's correlation coefficient. Multivariable linear regression was used to adjust for relevant clinical factors. A p value <0.05 was considered statistically significant.

Results: Of the 120 participants, 37 (30.8%) had mild, 49 (40.8%) had moderate and 34 (28.3%) had severe DNS. The mean age was 34.8±10.6 years, and 71 (59.2%) participants were male. Inferior turbinate hypertrophy, septal spur or contact point, mouth breathing, sleep disturbance and snoring increased significantly with DNS severity ($p\leq0.016$). The mean NOSE score increased from 36.6±12.2 in mild DNS to 58.3±12.4 in moderate and 77.9±11.9 in severe DNS ($F=99.64$, $p<0.001$). Post-decongestion PNIF decreased from 134.2±19.4 to 77.5±16.7 L/min, while nasal resistance increased from 0.21±0.06 to 0.52±0.12 Pa/cm³/s between the mild and severe groups (both $p<0.001$). Post-decongestion minimum cross-sectional area decreased from 0.66±0.11 to 0.31±0.08 cm², and nasal cavity volume decreased from 6.82±0.81 to 4.30±0.73 cm³ (both $p<0.001$). DNS severity correlated positively with NOSE score ($\rho=0.79$) and nasal resistance ($\rho=0.82$) and negatively with PNIF ($\rho=-0.78$), minimum cross-sectional area ($\rho=-0.84$) and nasal cavity volume ($\rho=-0.81$); all $p<0.001$. After adjustment, each one-level increase in DNS severity was associated with a 19.12-point increase in NOSE score and a 26.38 L/min reduction in PNIF.

Conclusion: Increasing DNS severity was independently associated with greater subjective symptom burden, reduced nasal airflow, increased nasal resistance and decreased nasal dimensions. Combined assessment using the NOSE scale and objective nasal airflow measurements may improve the functional evaluation and treatment planning of patients with symptomatic DNS.
Keywords: Deviated nasal septum; NOSE score; Nasal airflow.

INTRODUCTION

Deviated nasal septum (DNS) is one of the most frequent structural abnormalities encountered in otorhinolaryngology practice and is an important cause of persistent nasal obstruction. Deviation may involve the cartilaginous or bony septum and may vary considerably in its location, configuration and severity. Although many septal deviations remain asymptomatic, clinically significant deviation can disturb normal nasal airflow and produce nasal blockage, mouth breathing, sleep disturbance, snoring, headache, recurrent epistaxis and impaired quality of life.[1] The severity of symptoms, however, does not always correspond directly to the anatomical degree of septal deviation because nasal patency is also influenced by the nasal cycle, mucosal congestion, inferior turbinate hypertrophy, allergic rhinitis, nasal valve function and individual perception of airflow. Therefore, evaluation based exclusively on anterior rhinoscopy or nasal endoscopy may not adequately represent the functional burden experienced by the patient.[2]

The Nasal Obstruction Symptom Evaluation (NOSE) scale is a validated, reliable and responsive disease-specific instrument used to quantify the subjective severity of nasal obstruction. It consists of five items addressing nasal congestion, nasal blockage, difficulty breathing through the nose, sleep disturbance and inability to obtain adequate nasal airflow during exertion. Each item is scored from 0 to 4, and the total raw score is multiplied by five to generate a score ranging from 0 to 100; a higher score represents more severe nasal obstruction.[3] Although the NOSE scale provides an important patient-centred assessment, it remains subjective and may be influenced by symptom adaptation, expectations and associated sinonasal conditions.

Objective assessment of nasal patency can be performed using peak nasal inspiratory flow (PNIF), active anterior rhinomanometry and acoustic rhinometry. PNIF is a simple, rapid and non-invasive measurement of maximum inspiratory airflow through the nose. Rhinomanometry measures transnasal pressure and airflow and calculates nasal airway resistance, whereas acoustic rhinometry determines the minimum cross-sectional area and nasal cavity volume from reflected acoustic signals.[2,4] These methods evaluate different anatomical and physiological components of nasal patency and should therefore be considered complementary rather than interchangeable.

Previous studies have demonstrated only weak-to-moderate relationships between patient-reported nasal obstruction and objective airflow measurements. PNIF and rhinomanometric resistance may differentiate symptomatic from asymptomatic individuals, but anatomical severity, symptom burden and physiological impairment do not necessarily show a uniform association.[4,5]

Aim: To assess the association of deviated nasal septum severity with NOSE score and objective nasal airflow parameters among adult patients with nasal obstruction.

Objectives

1. To determine the anatomical severity and pattern of deviated nasal septum using anterior rhinoscopy and diagnostic nasal endoscopy.
2. To assess subjective nasal obstruction using the validated NOSE scale and measure objective nasal patency using PNIF, active anterior rhinomanometry and acoustic rhinometry.
3. To correlate DNS severity with NOSE score and objective nasal airflow parameters after controlling for relevant clinical factors.

MATERIALS AND METHODS

Source of Data: The study population comprised adult patients attending the Otorhinolaryngology outpatient department with complaints of persistent nasal obstruction and clinically diagnosed deviated nasal septum. Eligible patients who attended during the study period and provided written informed consent constituted the source of data.

Study Design: A hospital-based analytical cross-sectional study was conducted.

Study Location: The study was conducted in the Department of Otorhinolaryngology. Clinical and endoscopic examinations were performed in the ENT outpatient department. Objective nasal airflow measurements were performed in the rhinology or nasal physiology laboratory using calibrated instruments.

Study Duration: The study was conducted over 18 months, from January 2025 to June 2026, including participant recruitment, clinical evaluation, airflow assessment, data entry and statistical analysis.

Sample Size: The sample size was calculated for detecting a correlation between the NOSE score and objective nasal airflow measurements using Fisher's z transformation:

$$n=[(Z_{1-\alpha/2}+Z_{1-\beta})/(0.5 \ln((1+r)/(1-r)))]^2+3$$

Where:

$Z_{(1-\alpha/2)}$=1.96at a 5% level of significance;
$Z_{(1-\beta)}$=0.84for 80% statistical power;
r=0.27, the minimum anticipated correlation between subjective and objective nasal obstruction measurements.
n=[(1.96+0.84)/(0.5 ln((1+0.27)/(1-0.27)))]^2+3
n≈106
After allowing approximately 10% for incomplete observations or technically unacceptable measurements:
n_"adjusted" =106/(1-0.10)=117.8
The final sample size was rounded to 120 participants.

Sampling Method: Patients satisfying the eligibility criteria were recruited consecutively until the required sample size of 120 was achieved.

Inclusion Criteria

1. Patients aged 18-60 years.
2. Patients presenting with unilateral or bilateral nasal obstruction for at least three months.
3. Patients with DNS confirmed through anterior rhinoscopy and diagnostic nasal endoscopy.
4. Patients capable of understanding and completing the NOSE questionnaire.
5. Patients willing to provide written informed consent and undergo objective nasal airflow assessment.

Exclusion Criteria

1. Previous septoplasty, septorhinoplasty, turbinate surgery or other nasal surgery.
2. Acute upper respiratory tract infection during the preceding two weeks.
3. Active acute rhinosinusitis or acute exacerbation of allergic rhinitis.
4. Nasal polyposis, sinonasal tumour, septal perforation, nasal foreign body or gross external nasal deformity.
5. Clinically significant nasal valve collapse.
6. Recent nasal trauma or fracture.
7. Uncontrolled bronchial asthma or severe cardiopulmonary disease that could interfere with PNIF measurement.
8. Pregnancy or contraindication to topical nasal decongestants.
9. Inability to perform reproducible airflow measurements.
10. Incomplete questionnaire or missing clinical data.

Procedure and Methodology: After receiving approval from the Institutional Ethics Committee, potentially eligible patients were approached in the ENT outpatient department. The purpose and procedures of the study were explained, and written informed consent was obtained.

Clinical assessment: A detailed history was recorded regarding the duration, laterality and severity of nasal obstruction; mouth breathing; snoring; sleep disturbance; nasal discharge; sneezing; anosmia or hyposmia; headache; epistaxis; allergy; trauma; medication use and previous nasal surgery. Age, sex, occupation, smoking status, height, weight and body mass index were documented.

All participants underwent external nasal examination, anterior rhinoscopy and diagnostic nasal endoscopy using a rigid 0° nasal endoscope after topical anaesthesia and decongestion. The side, site and pattern of deviation were recorded. Associated inferior turbinate hypertrophy, septal spur, septal contact point and mucosal abnormalities were documented.

Based on the estimated percentage of nasal passage narrowing on the more obstructed side, DNS severity was categorized as:

- **Mild:** less than 50% obstruction;
- **Moderate:** 50-75% obstruction;
- **Severe:** more than 75% obstruction or septal contact with the lateral nasal wall/turbinate.

Whenever possible, endoscopic images were stored. A second ENT specialist, blinded to the NOSE score and airflow findings, independently graded a subset of examinations to determine interobserver agreement.

NOSE score assessment: Participants completed the validated NOSE questionnaire before learning the results of the objective tests. The questionnaire assessed five domains:

1. Nasal congestion or stuffiness;
2. Nasal blockage or obstruction;
3. Difficulty breathing through the nose;
4. Difficulty sleeping;
5. Inability to obtain sufficient air through the nose during exercise or exertion.

Each item was scored from 0 (“not a problem”) to 4 (“severe problem”). The item scores were added and multiplied by five. The resulting total score ranged from 0 to 100, with higher scores indicating greater symptom severity.

Standardization before airflow assessment: Participants were instructed to avoid nasal decongestants for at least 12 hours, intranasal corticosteroids on the morning of testing, smoking for two hours, and strenuous exercise or caffeinated beverages for one hour before assessment. They were allowed to acclimatize in the testing room for approximately 20 minutes. Room temperature and humidity were maintained as consistently as possible. All instruments were calibrated according to the manufacturer’s instructions.

Peak nasal inspiratory flow: PNIF was measured using a calibrated nasal inspiratory flow meter. The participant was seated upright and fitted with an airtight face mask covering the nose without compressing the external nasal valve. After complete expiration through the mouth, the participant inhaled forcefully through the nose with the mouth closed. Three technically acceptable measurements were obtained at intervals of approximately 30 seconds. The highest value was recorded in litres per minute.

Active anterior rhinomanometry: Active anterior rhinomanometry was performed according to standardized recommendations. Airflow and transnasal pressure were recorded separately for each nasal cavity during quiet breathing. Nasal resistance

was calculated at a standardized reference pressure of 150 Pa and expressed as Pa/cm³/second. Total bilateral nasal resistance was calculated from right- and left-sided measurements.

Acoustic rhinometry: Acoustic rhinometry was performed with the participant seated and the head maintained in a neutral position. A suitable nosepiece was applied without deforming the nostril. At least three acceptable measurements were taken for each nasal cavity. The minimum cross-sectional area and nasal cavity volume within the predefined anterior nasal segment were recorded.

Airflow investigations were performed before and approximately 10-15 minutes after the application of a standardized topical nasal decongestant. Post-decongestion measurements were considered the principal measurements for evaluating structural obstruction caused by DNS, while pre-decongestion values were retained to assess the contribution of mucosal congestion.

Sample Processing: No blood, tissue or other biological sample was collected; therefore, conventional laboratory sample processing was not applicable. In this study, "sample processing" referred to the quality control and processing of airflow measurements. Each measurement was checked immediately for air leakage, coughing, swallowing, irregular breathing, poor inspiratory effort or instrument error. Technically unacceptable recordings were repeated. Replicate measurements were reviewed for reproducibility, and the final PNIF, nasal resistance, minimum cross-sectional area and nasal volume values were entered into the study database.

Data Collection: Data were collected using a predesigned and pilot-tested case record form consisting of the following sections:

- Sociodemographic and anthropometric information;
- Nasal obstruction and relevant clinical history;
- Anterior rhinoscopy and nasal endoscopy findings;
- Site, side, type and severity of DNS;
- Inferior turbinate and nasal valve findings;
- Individual NOSE questionnaire responses and total score;
- Pre- and post-decongestion PNIF measurements;
- Rhinomanometric airflow and nasal resistance;
- Acoustic rhinometry measurements.

Each participant was assigned a unique identification number. Data were checked for completeness and consistency on the day of collection. Patient names were not entered into the analytical database. Access to the study records was restricted to the investigators.

Statistical Methods: Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics or an equivalent statistical package. Continuous variables were presented as mean with standard deviation when normally distributed and as median with interquartile range when non-normally distributed. Categorical variables were summarized using frequencies and percentages.

The Shapiro-Wilk test and graphical methods were used to assess normality. Mean NOSE score, PNIF, nasal resistance, minimum cross-sectional area and nasal volume were compared across mild, moderate and severe DNS groups using one-way analysis of variance with an appropriate post-hoc test. The Kruskal-Wallis test was used when parametric assumptions were not met. Categorical variables were compared using the chi-square test or Fisher's exact test.

The association of ordinal DNS severity with NOSE score and objective airflow parameters was evaluated using Spearman's rank correlation coefficient. Pearson's correlation was used for normally distributed continuous measurements. Agreement between the two observers regarding DNS severity was evaluated using weighted kappa statistics.

Multiple linear regression analysis was performed to determine the independent association of DNS severity with NOSE score, PNIF and nasal resistance after adjustment for age, sex, body mass index, duration of symptoms, allergic rhinitis and inferior turbinate hypertrophy. Regression coefficients were reported with 95% confidence intervals. A two-tailed p value <0.05 was considered statistically significant.

Ethical Considerations: Approval was obtained from the Institutional Ethics Committee before commencement of the study. Written informed consent was obtained from every participant. Confidentiality and anonymity were maintained throughout the study. Participation was voluntary, and refusal or withdrawal did not affect routine clinical care.

RESULTS

Table 1: Sociodemographic and clinical characteristics according to DNS severity (N=120)

Characteristic	Overall (N=120)	Mild DNS (n=37)	Moderate DNS (n=49)	Severe DNS (n=34)	Test statistic	95% CI of effect	p value
Age, years, Mean (SD)	34.8 (10.6)	33.1 (10.2)	34.7 (10.5)	36.8 (10.9)	F=1.08	Mean difference, severe vs mild: −1.31 to 8.71	0.343
Male sex, n (%)	71 (59.2)	19 (51.4)	29 (59.2)	23 (67.6)	χ^2=1.94	Cramér's V: 0.000-0.235	0.379
Female sex, n (%)	49 (40.8)	18 (48.6)	20 (40.8)	11 (32.4)			

BMI, kg/m², Mean (SD)	24.3 (3.7)	23.9 (3.5)	24.2 (3.8)	24.9 (3.7)	F=0.67	Mean difference, severe vs mild: −0.76 to 2.76	0.515
Symptom duration, months, Median (IQR)	19 (11-32)	13 (8-23)	19 (12-31)	28 (17-42)	H=13.42	Median difference, severe vs mild: 6.0-18.0	0.001
Predominantly unilateral obstruction, n (%)	73 (60.8)	18 (48.6)	31 (63.3)	24 (70.6)	χ^2=3.84	Cramér's V: 0.034-0.279	0.147
History of nasal trauma, n (%)	31 (25.8)	7 (18.9)	13 (26.5)	11 (32.4)	χ^2=1.70	Cramér's V: 0.000-0.224	0.427
Allergic rhinitis, n (%)	43 (35.8)	16 (43.2)	18 (36.7)	9 (26.5)	χ^2=2.19	Cramér's V: 0.000-0.241	0.335
Inferior turbinate hypertrophy, n (%)	58 (48.3)	11 (29.7)	26 (53.1)	21 (61.8)	χ^2=8.21	Cramér's V: 0.091-0.367	0.016
Septal spur/contact point, n (%)	39 (32.5)	4 (10.8)	17 (34.7)	18 (52.9)	χ^2=14.91	Cramér's V: 0.211-0.471	0.001
Mouth breathing, n (%)	67 (55.8)	13 (35.1)	28 (57.1)	26 (76.5)	χ^2=12.32	Cramér's V: 0.169-0.430	0.002
Sleep disturbance, n (%)	54 (45.0)	9 (24.3)	22 (44.9)	23 (67.6)	χ^2=13.52	Cramér's V: 0.187-0.447	0.001
Snoring, n (%)	62 (51.7)	12 (32.4)	27 (55.1)	23 (67.6)	χ^2=9.08	Cramér's V: 0.112-0.384	0.011

DNS severity distribution: Mild 37/120, 30.8% (95% CI: 23.3-39.6); moderate 49/120, 40.8% (95% CI: 32.4-49.8); and severe 34/120, 28.3% (95% CI: 21.0-37.0).

Among the 120 participants, moderate DNS was the most common category, observed in 49 (40.8%; 95% CI: 32.4-49.8%) patients, followed by mild DNS in 37 (30.8%; 95% CI: 23.3-39.6%) and severe DNS in 34 (28.3%; 95% CI: 21.0-37.0%). The mean age was 34.8±10.6 years, 71 (59.2%) participants were male, and the mean BMI was 24.3±3.7 kg/m². Age, sex and BMI did not differ significantly across DNS severity groups (p>0.05). The median duration of symptoms increased from 13 months in mild DNS to 28 months in severe DNS, and this difference was statistically significant (H=13.42, p=0.001; median difference: 6.0-18.0 months). Predominantly unilateral obstruction, history of nasal trauma and allergic rhinitis were not significantly associated with DNS severity (p>0.05). In contrast, inferior turbinate hypertrophy increased from 29.7% in mild DNS to 61.8% in severe DNS (χ^2=8.21, p=0.016). Septal spur or contact point was also more frequent in severe than mild DNS (52.9% versus 10.8%; χ^2=14.91, p=0.001). Mouth breathing (χ^2=12.32, p=0.002), sleep disturbance (χ^2=13.52, p=0.001) and snoring (χ^2=9.08, p=0.011) increased significantly with increasing DNS severity.

Table 2: NOSE scale scores according to DNS severity (N=120)

NOSE scale component	Overall Mean (SD)	Mild DNS (n=37)	Moderate DNS (n=49)	Severe DNS (n=34)	F statistic	Mean difference: severe vs mild (95% CI)	p value
Nasal congestion/stuffiness, 0-4	2.43 (0.93)	1.68 (0.67)	2.49 (0.68)	3.18 (0.63)	42.76	1.50 (1.17 to 1.83)	<0.001
Nasal blockage/obstruction, 0-4	2.51 (0.96)	1.65 (0.68)	2.59 (0.64)	3.32 (0.59)	59.31	1.67 (1.35 to 1.99)	<0.001
Trouble breathing through nose, 0-4	2.39 (0.99)	1.54 (0.69)	2.43 (0.71)	3.26 (0.62)	56.84	1.72 (1.38 to 2.06)	<0.001
Trouble sleeping, 0-4	1.93 (1.08)	1.14 (0.71)	1.94 (0.83)	2.76 (0.82)	36.48	1.62 (1.23 to 2.01)	<0.001
Unable to obtain enough air during exercise, 0-4	2.17 (1.03)	1.32 (0.71)	2.20 (0.74)	3.06 (0.69)	51.72	1.74 (1.38 to 2.10)	<0.001
Raw NOSE score, 0-20	11.43 (4.16)	7.32 (2.43)	11.65 (2.47)	15.59 (2.38)	99.64	8.27 (7.11 to 9.43)	<0.001
Total NOSE score, 0-100	57.1 (20.8)	36.6 (12.2)	58.3 (12.4)	77.9 (11.9)	99.64	41.3 (35.5 to 47.1)	<0.001

NOSE severity categories

NOSE severity category	Overall n (%)	Mild DNS n (%)	Moderate DNS n (%)	Severe DNS n (%)
Mild symptoms: 0-25	18 (15.0)	16 (43.2)	2 (4.1)	0 (0.0)
Moderate symptoms: 30-50	31 (25.8)	17 (45.9)	13 (26.5)	1 (2.9)
Severe symptoms: 55-75	42 (35.0)	4 (10.8)	27 (55.1)	11 (32.4)
Extreme symptoms: 80-100	29 (24.2)	0 (0.0)	7 (14.3)	22 (64.7)
Association				
χ^2, 95% CI and p value	χ^2=79.18		Cramér's V=0.482 (95% CI: 0.389-0.589)	p<0.001

The overall mean NOSE score was 57.1±20.8 (95% CI: 53.4-60.9). A progressive and statistically significant increase in every NOSE component was observed with increasing DNS severity. The mean

total NOSE score increased from 36.6±12.2 in mild DNS to 58.3±12.4 in moderate DNS and 77.9±11.9 in severe DNS (F=99.64, p<0.001). The mean difference between severe and mild DNS was 41.3 points (95% CI: 35.5-47.1). Similar trends were observed for nasal congestion, nasal blockage, difficulty breathing through the nose, sleep difficulty and inability to obtain sufficient air during exercise, with all comparisons being statistically significant (p<0.001). Mild or moderate symptoms were present in 33 (89.2%) patients with mild DNS, whereas 22 (64.7%) patients with severe DNS had extreme symptoms. Overall, anatomical DNS severity showed a strong and statistically significant association with NOSE symptom category (χ^2=79.18, Cramér's V=0.482; 95% CI: 0.389-0.589; p<0.001).

Table 3: Objective nasal airflow parameters according to DNS severity (N=120)

Objective parameter	Overall Mean (SD)	Mild DNS (n=37)	Moderate DNS (n=49)	Severe DNS (n=34)	F statistic	Mean difference: severe vs mild (95% CI)	p value
Pre-decongestion PNIF, L/min	91.8 (26.7)	119.6 (18.8)	88.9 (17.6)	65.8 (15.1)	86.37	−53.8 (−62.0 to −45.6)	<0.001
Post-decongestion PNIF, L/min	105.7 (28.1)	134.2 (19.4)	103.8 (18.3)	77.5 (16.7)	88.91	−56.7 (−65.4 to −48.0)	<0.001
Pre-decongestion total nasal resistance, Pa/cm³/s	0.43 (0.17)	0.27 (0.08)	0.43 (0.10)	0.61 (0.13)	90.26	0.34 (0.29 to 0.39)	<0.001
Post-decongestion total nasal resistance, Pa/cm³/s	0.35 (0.15)	0.21 (0.06)	0.34 (0.08)	0.52 (0.12)	102.73	0.31 (0.27 to 0.35)	<0.001
Pre-decongestion minimum cross-sectional area, cm²	0.42 (0.15)	0.58 (0.10)	0.41 (0.08)	0.26 (0.07)	117.42	−0.32 (−0.36 to −0.28)	<0.001
Post-decongestion minimum cross-sectional area, cm²	0.49 (0.17)	0.66 (0.11)	0.49 (0.09)	0.31 (0.08)	119.83	−0.35 (−0.40 to −0.30)	<0.001
Pre-decongestion nasal cavity volume, cm³	4.87 (1.19)	6.03 (0.78)	4.79 (0.71)	3.72 (0.66)	94.56	−2.31 (−2.68 to −1.94)	<0.001
Post-decongestion nasal cavity volume, cm³	5.56 (1.28)	6.82 (0.81)	5.49 (0.76)	4.30 (0.73)	97.18	−2.52 (−2.90 to −2.14)	<0.001

Objective nasal airflow measurements deteriorated progressively as DNS severity increased. Mean pre-decongestion PNIF decreased from 119.6±18.8 L/min in mild DNS to 65.8±15.1 L/min in severe DNS, with a mean difference of −53.8 L/min (95% CI: −62.0 to −45.6; F=86.37, p<0.001). Post-decongestion PNIF similarly declined from 134.2±19.4 to 77.5±16.7 L/min (mean difference: −56.7 L/min; 95% CI: −65.4 to −48.0; F=88.91, p<0.001). Conversely, post-decongestion nasal resistance increased from 0.21±0.06 Pa/cm³/s in mild DNS to 0.52±0.12 Pa/cm³/s in severe DNS (mean difference: 0.31; 95% CI: 0.27-0.35; F=102.73, p<0.001). Post-decongestion minimum cross-sectional area decreased from 0.66±0.11 cm² to 0.31±0.08 cm² (mean difference: −0.35 cm²; 95% CI: −0.40 to −0.30; F=119.83, p<0.001), while nasal cavity volume declined from 6.82±0.81 cm³ to 4.30±0.73 cm³ (mean difference: −2.52 cm³; 95% CI: −2.90 to −2.14; F=97.18, p<0.001). Post-hoc comparisons confirmed significant differences among mild, moderate and severe DNS groups for every objective parameter (all adjusted p<0.001).

Table 4: Correlation and adjusted association of DNS severity with NOSE score and objective nasal airflow parameters (N=120)

A. Unadjusted correlation analysis

Outcome parameter	Spearman's correlation with DNS severity (ρ)	95% CI for ρ	Test statistic (t)	p value
Total NOSE score	0.79	0.71 to 0.85	14.01	<0.001
Pre-decongestion PNIF	−0.77	−0.84 to −0.68	−13.12	<0.001
Post-decongestion PNIF	−0.78	−0.85 to −0.70	−13.54	<0.001
Pre-decongestion nasal resistance	0.80	0.72 to 0.86	14.50	<0.001
Post-decongestion nasal resistance	0.82	0.75 to 0.87	15.59	<0.001
Pre-decongestion minimum cross-sectional area	−0.83	−0.88 to −0.76	−16.16	<0.001
Post-decongestion minimum cross-sectional area	−0.84	−0.89 to −0.78	−16.83	<0.001
Post-decongestion nasal cavity volume	−0.81	−0.86 to −0.73	−14.93	<0.001

B. Multivariable linear regression analysis

Dependent variable	Main predictor	Adjusted regression coefficient (β)	95% CI	t value	p value	Adjusted R^2
Total NOSE score	Each one-level increase in DNS severity	19.12 points	16.02 to 22.22	12.20	<0.001	0.68
Post-decongestion PNIF	Each one-level increase in DNS severity	−26.38 L/min	−30.92 to −21.84	−11.50	<0.001	0.66
Post-decongestion nasal resistance	Each one-level increase in DNS severity	0.149 Pa/cm³/s	0.126 to 0.172	12.81	<0.001	0.71
Post-decongestion minimum cross-sectional area	Each one-level increase in DNS severity	−0.171 cm²	−0.197 to −0.145	−13.02	<0.001	0.73
Post-decongestion nasal cavity volume	Each one-level increase in DNS severity	−1.19 cm³	−1.39 to −0.99	−11.78	<0.001	0.67

Unadjusted correlation analysis demonstrated a strong positive correlation between DNS severity and total NOSE score (ρ=0.79; 95% CI: 0.71-0.85; t=14.01; p<0.001). DNS severity was strongly and negatively correlated with pre- and post-decongestion PNIF, minimum cross-sectional area and nasal cavity volume, with correlation coefficients ranging from −0.77 to −0.84 (all p<0.001). In contrast, increasingly severe DNS was positively correlated with pre-decongestion nasal resistance (ρ=0.80; 95% CI: 0.72-0.86) and post-decongestion nasal resistance (ρ=0.82; 95% CI: 0.75-0.87), both p<0.001. After adjustment for age, sex, BMI, symptom duration, allergic rhinitis, inferior turbinate hypertrophy and nasal trauma, each one-level increase in DNS severity was associated with a 19.12-point increase in NOSE score (95% CI: 16.02-22.22; p<0.001), a 26.38 L/min reduction in PNIF (95% CI: −30.92 to −21.84; p<0.001), and a 0.149 Pa/cm³/s increase in nasal resistance (95% CI: 0.126-0.172; p<0.001). It was also associated with reductions of 0.171 cm² in the minimum cross-sectional area and 1.19 cm³ in nasal cavity volume (both p<0.001). The adjusted models explained 66%-73% of the variability in the respective outcomes, confirming that DNS severity was an independent determinant of subjective obstruction and objectively impaired nasal airflow.

DISCUSSION

The present cross-sectional study evaluated the relationship between anatomical DNS severity, patient-reported nasal obstruction and objective nasal airflow parameters among 120 adults. Moderate DNS was the most frequent category, accounting for 40.8% of the participants, while 30.8% had mild and 28.3% had severe DNS. The participants were relatively young, with a mean age of 34.8±10.6 years, and males constituted 59.2% of the study population. Age, sex and BMI did not differ significantly across the DNS severity categories, suggesting that the observed variation in symptoms and airflow parameters was mainly associated with anatomical and local clinical factors rather than demographic differences.

Teixeira et al. (2016).[1] in a systematic review of nasal septal deviation classification systems, reported considerable heterogeneity in the description and grading of DNS. This lack of a universally accepted grading system may partly explain differences in the prevalence of mild, moderate and severe DNS across studies. Rimmer et al. (2019).[2] similarly emphasized that the anatomical extent of septal deviation should be interpreted alongside nasal endoscopy, patient-reported symptoms and physiological measurements. The present results support this multidimensional approach because DNS severity was related to both subjective symptom burden and objective airflow impairment.

The median duration of nasal obstruction increased significantly from 13 months among patients with mild DNS to 28 months among those with severe DNS. This finding suggests that patients with more advanced structural obstruction may experience persistent symptoms for a longer period before seeking specialist treatment. The higher male representation was comparable with several hospital-based septoplasty studies, although sex was not independently associated with DNS severity. Cantone et al. (2018).[3] observed that demographic characteristics alone were inadequate predictors of the functional impact or outcome of septal deviation. Inferior turbinate hypertrophy increased significantly from 29.7% in mild DNS to 61.8% in severe DNS. Compensatory hypertrophy of the turbinate opposite the deviated septum and mucosal enlargement on the obstructed side can further reduce the functional airway. The RIGA consensus reported by Vogt et al. (2018).[4] emphasized that nasal resistance is determined by the combined influence of the septum, turbinates, nasal valve and mucosal congestion rather than the septum alone. The significant increase in septal spurs or contact points from 10.8% in mild DNS to 52.9% in severe DNS also indicated that localized anatomical narrowing contributed substantially to symptom severity.

Mouth breathing, sleep disturbance and snoring became progressively more common as DNS severity increased. Mouth breathing was reported by 76.5% of patients with severe DNS compared with 35.1% of those with mild DNS, while sleep disturbance increased from 24.3% to 67.6%. Alghamdi et al. (2022).[5] described chronic nasal obstruction, mouth breathing, snoring and sleep-related complaints as important clinical consequences of significant septal deviation. Yeom et al. (2021).[6] in a nationwide cohort study, also identified an association between

septal deviation and subsequent obstructive sleep apnoea diagnosis. Although polysomnography was not performed in the present study, the increase in snoring and sleep disturbance indicates that severe DNS may have clinically relevant consequences beyond daytime nasal blockage.

Allergic rhinitis was present in 35.8% of participants but was not significantly associated with anatomical DNS severity. This is understandable because allergic rhinitis principally affects mucosal congestion and may increase symptom burden at any anatomical grade. Ishii et al. (2017).[7] recommended assessment of rhinitis, turbinate hypertrophy and nasal valve dysfunction when evaluating structural nasal obstruction because these conditions may modify symptoms and treatment outcomes.

The overall mean NOSE score was 57.1±20.8, indicating substantial patient-perceived nasal obstruction. The mean score increased progressively from 36.6±12.2 in mild DNS to 58.3±12.4 in moderate DNS and 77.9±11.9 in severe DNS. The 41.3-point difference between the severe and mild groups was statistically significant and substantially greater than the generally accepted minimum clinically important difference for the NOSE scale. Severe or extreme symptoms were observed in most patients with moderate-to-severe anatomical deviation.

Shukla et al. (2020).[8] demonstrated that the NOSE scale was a practical and sensitive instrument for assessing the severity of nasal obstruction and the symptomatic benefits of septal surgery. Their study identified nasal blockage and difficulty breathing through the nose as prominent symptoms, consistent with the present observation that these items had the highest scores. Gerecci et al. (2019).[9] reported high preoperative NOSE scores among patients undergoing functional septorhinoplasty and substantial improvement after anatomical correction, supporting the clinical responsiveness of the scale.

Floyd et al. (2017).[10] in a systematic review and meta-analysis, found large reductions in NOSE scores after functional rhinoplasty and septal surgery. Similarly, Carrie et al. (2024).[11] in the NAIROS randomized trial, showed that septoplasty was more effective than medical management in adults with symptomatic septal deviation, particularly among patients with greater baseline symptom severity. These studies indirectly support the present finding that increasing structural severity was accompanied by higher NOSE scores and suggest that patients with severe symptoms may obtain meaningful benefit from appropriately selected surgical treatment.

Nevertheless, the relationship between anatomical deviation and subjective obstruction is not uniform across all published studies. Lepley et al. (2023).[12] found that otolaryngologists could not reliably infer the presence of obstructive symptoms solely from the degree of septal deviation observed on CT. Zasadzińska-Stempniak et al. (2024).[13] also reported that the type and severity of septal deviation were not consistently related to subjective nasal patency. These differences may be explained by the influence of the nasal valve, turbinate size, mucosal disease, nasal cycle and sensory perception. The stronger relationship in the present study may also reflect the inclusion of symptomatic patients with clinically confirmed DNS and the use of decongested endoscopic assessment.

The objective measurements demonstrated consistent deterioration in nasal function with increasing DNS severity. Pre-decongestion PNIF decreased from 119.6±18.8 L/min in mild DNS to 65.8±15.1 L/min in severe DNS. Post-decongestion PNIF also declined from 134.2±19.4 to 77.5±16.7 L/min. Thus, the severe group retained markedly lower airflow even after mucosal decongestion, indicating that structural obstruction rather than reversible mucosal congestion was the predominant contributor.

Fuller et al. (2018).[14] reported that PNIF was a simple, inexpensive and clinically useful objective measure of nasal obstruction and functional septorhinoplasty outcome. Bora et al. (2022).[15] similarly found that PNIF varied according to the severity and type of septal deviation, supporting the progressive decline observed in the present study. Ottaviano et al. (2022).[16] reported significantly lower PNIF values among symptomatic participants and demonstrated significant relationships between PNIF, rhinomanometry and patient-reported symptoms. The present findings agree with these observations, although the magnitude of correlation was higher in the current study.

Nasal resistance increased substantially with DNS severity. Post-decongestion total nasal resistance was 0.21±0.06 Pa/cm³/s in mild DNS compared with 0.52±0.12 Pa/cm³/s in severe DNS. This represented a mean difference of 0.31 Pa/cm³/s. Rhinomanometry provides a dynamic assessment of nasal ventilation by relating transnasal pressure to airflow. Patil et al. (2024).[17] described rhinomanometry as an important objective technique for documenting physiological obstruction and assessing the functional effects of nasal surgery. The persistence of high resistance after decongestion in the severe group strengthens the evidence that the obstruction was predominantly anatomical.

Acoustic rhinometry showed a corresponding reduction in nasal dimensions. Post-decongestion minimum cross-sectional area decreased from 0.66±0.11 cm² in mild DNS to 0.31±0.08 cm² in severe DNS, while nasal cavity volume decreased from 6.82±0.81 to 4.30±0.73 cm³. Demirhan et al. (2021).[18] demonstrated that acoustic rhinometry and active anterior rhinomanometry could objectively document changes in nasal dimensions and resistance following septal surgery. The present cross-sectional results extend this observation by demonstrating a clear severity gradient before treatment.

Haque et al. (2023).[19] reported significant improvement in both subjective symptoms and objective nasal measurements following septoplasty. Srinivasan et al. (2022).[20] likewise demonstrated improvement in PNIF and symptom scores among

patients managed surgically. These intervention studies support the biological plausibility of the current findings: correction of the structural narrowing increases the effective cross-sectional area, reduces resistance and improves nasal airflow.

The correlation analysis demonstrated a strong positive relationship between DNS severity and total NOSE score (ρ=0.79). DNS severity was also positively correlated with post-decongestion nasal resistance (ρ=0.82) and negatively correlated with PNIF (ρ=−0.78), minimum cross-sectional area (ρ=−0.84) and nasal cavity volume (ρ=−0.81). Thus, the anatomical, subjective and physiological findings followed a consistent dose-response pattern.

Ottaviano et al. (2022).[16] found weak-to-moderate correlations between subjective symptoms and PNIF or rhinomanometry, while emphasizing that each method evaluates a different component of nasal obstruction. Rimmer et al. (2019).[2] similarly concluded that no single test completely represents perceived nasal patency. In comparison, the stronger correlations in the present study may be attributable to the use of a clearly categorized anatomical severity variable, exclusion of major competing causes of obstruction and standardized post-decongestion measurements.

Malik et al. (2022).[21] showed that the perception of nasal patency depends not only on resistance but also on mucosal cooling and trigeminal sensory function. This explains why some individuals with substantial structural deviation may report limited symptoms, whereas others with comparatively modest narrowing experience marked obstruction. Therefore, the high correlations observed in the present study should not imply that objective testing can replace patient-reported assessment. Instead, NOSE scoring, nasal endoscopy, PNIF, rhinomanometry and acoustic rhinometry should be regarded as complementary measures.

After controlling for age, sex, BMI, symptom duration, allergic rhinitis, inferior turbinate hypertrophy and nasal trauma, each one-level increase in DNS severity was independently associated with a 19.12-point increase in NOSE score, a 26.38 L/min reduction in PNIF, a 0.149 Pa/cm³/s increase in nasal resistance, a 0.171 cm² reduction in minimum cross-sectional area and a 1.19 cm³ reduction in nasal cavity volume. The adjusted models explained 66%-73% of the variability in these outcomes. These findings suggest that DNS severity remained an important independent determinant of both perceived and measured obstruction even after relevant confounders were considered.

Wu et al. (2024).[22] in a meta-analysis examining septoplasty among patients with septal deviation and allergic rhinitis, concluded that structural correction could improve nasal symptoms even when mucosal disease coexisted, although associated rhinitis required continued medical management. This supports the present adjusted analysis, in which DNS severity remained significantly associated with obstruction after allergic rhinitis and turbinate hypertrophy were included in the model.

CONCLUSION

Increasing severity of deviated nasal septum was significantly associated with greater subjective nasal obstruction and progressive impairment of objective nasal airflow. Patients with severe DNS had substantially higher NOSE scores, lower peak nasal inspiratory flow, higher nasal airway resistance, and smaller minimum cross-sectional area and nasal cavity volume than patients with mild or moderate DNS. Severe DNS was also associated with longer symptom duration and greater frequencies of inferior turbinate hypertrophy, septal contact points, mouth breathing, sleep disturbance and snoring. These relationships remained statistically significant after controlling for age, sex, BMI, symptom duration, allergic rhinitis, inferior turbinate hypertrophy and previous nasal trauma. The findings support the combined use of the NOSE scale, nasal endoscopy, PNIF, active anterior rhinomanometry and acoustic rhinometry for comprehensive evaluation of patients with symptomatic DNS. Treatment decisions should be based on both patient-reported symptom burden and objective functional impairment rather than anatomical appearance alone.

Limitations

1. The cross-sectional design established associations but could not determine temporal relationships or prove that increasing DNS severity directly caused the observed symptoms and airflow abnormalities.
2. The study was conducted at a single tertiary care hospital; therefore, the participants might not represent patients treated in primary care or the general population.
3. Consecutive sampling could have introduced selection bias, particularly because patients attending a tertiary ENT department may have had more severe or persistent symptoms.
4. The sample size was relatively modest, particularly after dividing participants into mild, moderate and severe DNS groups.
5. DNS severity was graded through clinical and endoscopic estimation of nasal passage narrowing. Although clinically practical, this method may have been affected by observer-related variation.
6. The NOSE scale was a patient-reported instrument and could have been influenced by individual symptom perception, adaptation to chronic obstruction, psychological factors and expectations.
7. PNIF depended on respiratory effort, participant cooperation and technique; therefore, it might not have represented nasal resistance independently of pulmonary function.
8. The nasal cycle and short-term changes in mucosal congestion could have influenced

rhinomanometric and acoustic rhinometric measurements despite standardization and decongestion.

9. Although relevant variables were included in the regression models, residual confounding from nasal valve dysfunction, environmental exposure, smoking, mild rhinitis and unrecognized sinonasal disease could not be completely excluded.
10. Polysomnography was not performed; therefore, the observed associations with snoring and sleep disturbance could not be related to objectively confirmed sleep-disordered breathing.
11. Healthy participants without DNS were not included as a control group, limiting comparisons with normal NOSE scores and airflow values.
12. The study did not include follow-up after medical treatment or septoplasty; consequently, the ability of baseline severity and airflow parameters to predict treatment outcomes could not be evaluated.

REFERENCES

1. Teixeira J, Certal V, Chang ET, Camacho M. Nasal septal deviations: a systematic review of classification systems. Plast Surg Int. 2016;2016:7089123. doi:10.1155/2016/7089123.
2. Rimmer J, Hellings P, Lund VJ, Alobid I, Beale T, Dassi C, et al. European position paper on diagnostic tools in rhinology. Rhinology. 2019;57(Suppl S28):1-41. doi:10.4193/Rhin19.410.
3. Cantone E, Ricciardiello F, Oliva F, De Corso E, Iengo M. Septoplasty: is it possible to identify potential predictors of surgical success? Acta Otorhinolaryngol Ital. 2018;38(6):528-535. doi:10.14639/0392-100X-2099.
4. Vogt K, Bachmann-Harildstad G, Lintermann A, Nechyporenko A, Peters F, Wernecke KD. The new agreement of the international RIGA consensus conference on nasal airway function tests. Rhinology. 2018;56(2):133-143. doi:10.4193/Rhin17.084.
5. Alghamdi FS, Albogami D, Alsurayhi AS, Alshibely AY, Alkaabi TH, Alqurashi LM, et al. Nasal septal deviation: a comprehensive narrative review. Cureus. 2022;14(11):e31317. doi:10.7759/cureus.31317.
6. Yeom SW, Kim MG, Lee EJ, Kim YJ, Lee SA, Yoon JH, et al. Association between septal deviation and obstructive sleep apnea diagnoses: a nationwide 9-year follow-up cohort study. J Clin Sleep Med. 2021;17(10):2099-2106. doi:10.5664/jcsm.9352.
7. Ishii LE, Tollefson TT, Basura GJ, Rosenfeld RM, Abramson PJ, Chaiet SR, et al. Clinical practice guideline: improving nasal form and function after rhinoplasty. Otolaryngol Head Neck Surg. 2017;156(2 Suppl):S1-S30. doi:10.1177/0194599816683153.
8. Shukla RH, Nemade SV, Shinde KJ. Comparison of visual analogue scale and the Nasal Obstruction Symptom Evaluation score in evaluation of post-septoplasty patients. World J Otorhinolaryngol Head Neck Surg. 2020;6(1):53-58.
9. Gerecci D, Casanueva FJ, Mace JC, Sedaghat AR, Smith TL. Nasal Obstruction Symptom Evaluation score outcomes after septorhinoplasty. Laryngoscope. 2019;129(4):841-846. doi:10.1002/lary.27578.
10. Floyd EM, Ho S, Patel P, Rosenfeld RM, Gordin E. Systematic review and meta-analysis of studies evaluating functional rhinoplasty outcomes with the NOSE score. JAMA Facial Plast Surg. 2017;19(6):463-469. doi:10.1001/jamafacial.2017.0805.
11. Carrie S, O'Hara J, Fouweather T, Homer T, Rousseau N, Rooshenas L, et al. Effectiveness of septoplasty compared to medical management in adults with obstruction associated with a deviated nasal septum: the NAIROS RCT. Health Technol Assess. 2024;28(10):1-68.
12. Lepley TJ, Frusciante RP, Malik J, Farag A, Otto BA, Zhao K. Otolaryngologists' radiological assessment of nasal septum deviation symptomatology. Eur Arch Otorhinolaryngol. 2023;280(1):235-240. doi:10.1007/s00405-022-07528-y.
13. Zasadzińska-Stempniak K, Gawlikowska-Sroka A, Rotter I. Correlation between subjective nasal patency and nasal septum morphology among adults. J Clin Med. 2024;13(9):2506. doi:10.3390/jcm13092506.
14. Fuller JC, Bernstein CH, Levesque PA, Lindsay RW. Peak nasal inspiratory flow as an objective measure of nasal obstruction and functional septorhinoplasty outcomes. JAMA Facial Plast Surg. 2018;20(2):175-176.
15. Bora A, Aslan Y, Durmuş K, Eren SB. Do mean values of the peak inspiratory nasal flowmeter vary according to the severity, direction and type of nasal septum deviation? Indian J Otolaryngol Head Neck Surg. 2022;74(Suppl 2):1989-1994.
16. Ottaviano G, Pendolino AL, Scarpa B, Torsello M, Sartori D, Savietto E, et al. Correlations between peak nasal inspiratory flow, acoustic rhinometry, 4-phase rhinomanometry and reported nasal symptoms. J Pers Med. 2022;12(9):1513. doi:10.3390/jpm12091513.
17. Patil N, Kulkarni N, Kumar S, Patil P. Rhinomanometry: a comprehensive review of its applications and advancements in rhinology practice. Cureus. 2024;16:e58717.
18. Demirhan E, Çukurova İ, Arslan İB, Bayol Ü, Eren E. Objective and subjective evaluation of nasal obstruction following septoplasty using acoustic rhinometry, rhinomanometry and symptom scores. Eur Arch Otorhinolaryngol. 2021;278:4347-4354.
19. Haque M, Khan MA, Ahmed N, Islam MR. Objective and subjective analysis for efficaciousness of nasal septal surgery. Indian J Otolaryngol Head Neck Surg. 2023;75(Suppl 1):447-453.
20. Srinivasan DG, Kunnath MS, Varghese AM, Mathew LM. Comparison of the efficacy of septoplasty with nonsurgical management in improving nasal obstruction in patients with deviated nasal septum. Int Arch Otorhinolaryngol. 2022;26(2):e280-e286.
21. Malik J, Spector BM, Wu Z, Kimbell JS, Lee SE, Farag AA, et al. Evidence of nasal cooling and sensory impairments driving patient symptoms with septal deviation. Laryngoscope. 2022;132(3):509-517. doi:10.1002/lary.29673.
22. Wu Y, Wang T, Liu Q, Zhao Y, Chen X. The benefits of septoplasty for patients with deviated nasal septum and allergic rhinitis: a meta-analysis. Sci Rep. 2024;14:26929.