

## ORIGINAL STUDY

# Beyond the horizontal – impact of body position on nasal dynamics: insights from 4-phase positional rhinomanometry

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## ABSTRACT

**BACKGROUND.** Positive posture reaction is a common concern in obstructive sleep apnea (OSA) patients, which affects both their sleep quality and overall health-related quality of life. Rhinomanometry has been used as a functional test to assess nasal airway resistance (NAR) and measure nasal airflow (NAF).

**OBJECTIVE.** We conducted this study using 4-phase positional rhinomanometry (4PPR) to investigate potential correlations between NAR and NAF when comparing the sitting and supine positions through the use of 4PPR.

**MATERIAL AND METHODS.** This cross-sectional study involved a consecutive group of adult patients (n=115) diagnosed with OSA, aged 18 to 60 years. 4PPR evaluation was conducted in accordance with consensus guidelines. The assessments were carried out in both the sitting position and after 10 minutes in the supine position. Correlation and comparative analyses were conducted using Pearson correlation, Spearman rank correlation, paired t-tests, and the Kruskal-Wallis test.

**RESULTS.** A statistically significant increase in total NAR (mean difference: +0.09 Pa/cm<sup>3</sup>/sec, p=0.048) and a significant decrease in total NAF (mean difference: -52.1 mL/sec, p=0.001) were observed during the transition from sitting to supine. Subgroup analysis revealed a significant rise in NAR for the right nasal cavity (p=0.0001), while the left side showed a non-significant increase (p=0.114). Both nostrils showed significant reductions in NAF (right: p=0.001, left: p=0.000). Classification of nasal obstruction based on sitting NAR and NAF indicated that patients with higher baseline NAR showed greater sensitivity to positional changes (Spearman's  $\rho = -0.42$ , p<0.001). Conversely, changes in NAF were less dependent on baseline airflow ( $\rho = -0.15$ , p=0.12), suggesting alternative influencing factors.

**CONCLUSION.** From our observations, it is clearly evident that the total nasal airway resistance increases, and the nasal airflow reduces on lying down, the primary source of variation being the posture changing. This finding is valuable in snorers and sleep apnea patients. 4-phase positional rhinomanometry should be performed to diagnose upper airway collapse in the supine position as part of the OSA evaluation.

**KEYWORDS:** rhinomanometry, OSA, nasal obstruction, nasal resistance, snoring, sleep apnea.

## INTRODUCTION

Experiencing nasal obstruction while lying down and during sleep is a common concern for individuals seeking ear, nose, and throat (ENT) assistance due to chronic nasal issues. This condition was first described and named as “positive posture reaction” by Rundcrantz<sup>1</sup>. The condition aggravates more during the night and is associated

with disruptions in both sleep quality and overall health-related quality of life (QOL)<sup>2,7</sup>.

Various techniques are currently available for the subjective and objective measurement of nasal blockage and nasal resistance. Rhinomanometry, a widely recognized functional test for assessing nasal physiology, has been in use since 1899 and was introduced as a clinical procedure in the 1970s by Cottle and Masing<sup>8</sup>. The four-phase rhino-

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manometry (4PR), which is an objective method for assessing nasal resistance and conductance during both the inspiratory and expiratory phases, was introduced in 2009 by 12 members of an international and interdisciplinary consortium and is now considered the gold standard for measuring nasal airway resistance<sup>9</sup>.

Studies have demonstrated that postural changes significantly influence nasal resistance and intranasal geometry in individuals with chronic nasal obstruction, allergic rhinitis, and healthy populations<sup>2,7,10-14</sup>. De Vito et al.<sup>10</sup> recommended performing rhinomanometry (RM) in seated and recumbent body positions, naming this assessment positional rhinomanometry. However, in patients with obstructive sleep apnea (OSA), nearly all publications refer to classic rhinomanometry, and controversies persist regarding the impact of positional changes on nasal obstruction and airflow<sup>3,5,15-17</sup>.

This study focuses on evaluating changes in nasal airway resistance (NAR) and nasal airflow (NAF) with positional changes in patients with OSA using 4-phase positional rhinomanometry (4PPR). The primary aim was to investigate potential correlations between NAR and NAF in the sitting and supine positions. Additionally, we aimed to classify nasal resistance into degrees of obstruction, assess the association of these degrees with positional changes, and establish correlations between obstruction severity and NAR/NAF variations. This approach seeks to enhance understanding of positional sensitivity in OSA patients and explore its potential implications for therapy and management.

The nasal airway contributes more than 50% to

upper airway resistance in patients with OSA. Increased nasal resistance can augment upper airway collapse in OSA<sup>17,18</sup>. Studies in individuals with sleep apnea have proposed rhinomanometry as a valuable tool for predicting the effects of structural nasal modifications, assessing adherence to nasal continuous positive airway pressure (CPAP) treatment, and determining optimal CPAP pressure settings<sup>3,18-20</sup>.

By leveraging 4PPR, this study provides a detailed assessment of positional changes in nasal physiology, addressing gaps in understanding their implications for OSA management and therapeutic strategies.

## MATERIAL AND METHODS

This cross-sectional study involved a consecutive group of adult patients diagnosed with obstructive sleep apnea (OSA). The research was conducted at the Department of Otolaryngology at AIG Hospitals in Hyderabad, India, adhering to the principles outlined in the Declaration of Helsinki. The study was approved by the Institutional Ethics Committee, and informed consent was obtained from all participants prior to their enrolment. Those who did not meet the inclusion criteria were excluded from the study.

### Inclusion criteria

- Adults aged 18 to 60 years.
- Positive history of sleep-disordered breathing or snoring.
- Apnea-Hypopnea Index (AHI) >5 events/hour on polysomnography.



**Figure 1.** Performing 4-Phase Positional Rhinomanometry: (A) in sitting position and (B) in supine position.

**Table 1. Comparison of NAR between the sitting and supine positions.**

Parameter	Sitting	Supine	Difference	P-value	Significance
Total NAR	0.32±0.12 (0.29–0.35)	0.41±0.15 (0.37–0.45)	+0.09	0.048	Significant
Right NAR	0.17±0.08 (0.15–0.19)	0.24±0.10 (0.21–0.27)	+0.07	0.0001	Significant
Left NAR	0.15±0.07 (0.13–0.17)	0.17±0.09 (0.15–0.20)	+0.02	0.114	Not Significant

### Exclusion criteria

- Central sleep apnea.
- History of nasal or palate surgeries.
- Facio-maxillary trauma or sinonasal / nasopharyngeal malignancies.
- Acute or chronic sinonasal inflammatory conditions (e.g., allergic or infective rhinosinusitis).
- Nasal mass lesions detected during diagnostic nasal endoscopy (e.g., nasal polyposis, adenoid hypertrophy).
- Smoking or acute nasal symptoms within the preceding week.
- Use of topical or oral medications that may alter nasal mucosa.

### Rhinomanometry

Four-phase positional rhinomanometry (4PPR) was performed following consensus guidelines to objectively assess nasal airway resistance and airflow. Each subject underwent two evaluations (Figure 1):

1. Sitting Position: Measurements were recorded while seated upright.
2. Supine Position: After transitioning to the supine posture, measurements were taken following a 10-minute acclimatization period.

To standardize the methodology:

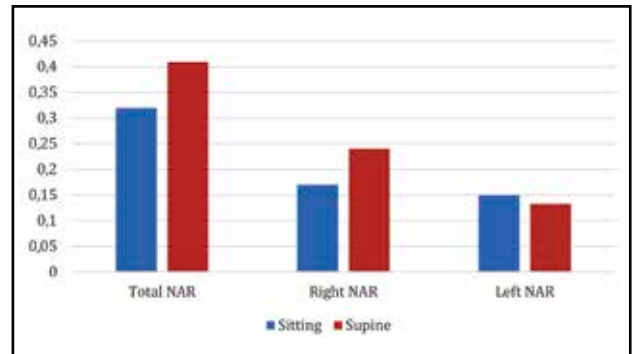
- A pressure-sensitive probe was attached to one nostril using adhesive sealing tape.
- Nasal airflow was measured through the contralateral nostril using an airtight mask covering the nose and mouth.
- The parameters recorded included total NAR (Pa/cm<sup>3</sup>/sec) and NAF (mL/sec) for both positions.

All procedures were completed within 20 minutes for each subject to minimize the impact of the nasal cycle on measurements.

### Statistical analyses

Statistical analyses were performed using SPSS® (version 25) statistical software, chosen for its comprehensive suite of statistical tools, user-friendly interface, and established reliability in medical research contexts. Pearson correlation analysis, based on Fisher's r-to-z transformation, was initially used to explore relationships between sitting NAR versus supine NAR and sitting NAF versus supine NAF.

Spearman rank correlation was employed to assess non-parametric associations, particularly for positional



**Figure 2.** Comparison of NAR between the sitting and supine positions.

sensitivity, as it accounts for ordinal data and potential non-linearity in relationships. This made it more suitable than Pearson correlation for analyzing the observed variability in positional sensitivity. Additionally, paired t-tests and the Kruskal-Wallis test were applied to evaluate positional changes in NAR and NAF. The level of significance was set at a two-tailed  $p$ -value  $\leq 0.05$ .

## RESULTS

After applying the inclusion and exclusion criteria, data from 115 patients who underwent four-phase positional rhinomanometry (4PPR) were analysed. Male and female subjects were regarded as a single group for statistical analysis.

### 1. Nasal Airway Resistance (NAR)

The mean values for NAR (mean  $\pm$  SD with 95% CI) in both positions and for each nostril are as presented in Table 1 and Figure 2.

A statistically significant increase in total NAR was noted when transitioning from sitting to supine ( $p=0.048$ ). The right nostril exhibited a significant increase ( $p=0.0001$ ), while the left nostril's increase was not statistically significant ( $p=0.114$ ).

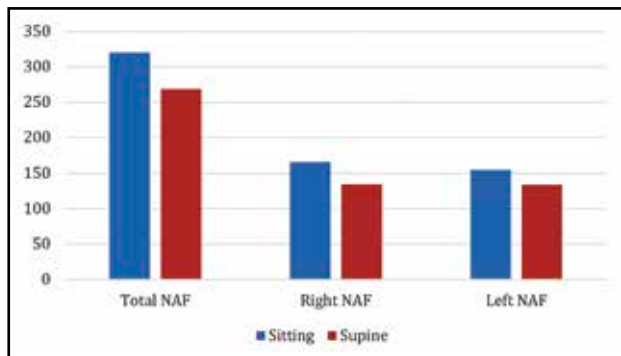
### 2. Nasal Airflow (NAF)

The mean values for NAF (mean  $\pm$  SD, with 95% CI) in both positions and for each nostril are presented in Table 2 and Figure 3.

A significant reduction in total NAF was observed when transitioning from the sitting to the supine position ( $p=0.001$ ). Both the right and left nasal cavities demonstrated significant decreases in airflow ( $p<0.001$  for each

**Table 2. Comparison of NAF between the sitting and supine positions.**

Parameter	Sitting	Supine	Difference	P-value	Significance
Total NAF	320.6±55.4 (310.4–330.8)	268.5±60.2 (257.2–279.8)	-52.1	0.001	Significant
Right NAF	165.8±39.2 (158.2–173.4)	134.6±44.3 (126.1–143.1)	-31.2	0.001	Significant
Left NAF	154.8±38.5 (147.3–162.3)	133.9±41.5 (126.1–141.7)	-20.9	0.000	Significant

**Figure 3.** Comparison of NAF between the sitting and supine positions.

nostril). These findings confirm that positional changes significantly affect nasal airflow.

### 3. Correlation between severity of nasal obstruction and positional changes

Using NAR and NAF values in the sitting position, patients were classified into degrees of nasal obstruction, based on established thresholds derived from clinical guidelines and research literature<sup>21-23</sup>. For NAR, thresholds were defined as follows: Normal ( $\leq 0.25$ ), Mild Obstruction (0.26–0.35), Moderate Obstruction (0.36–0.45), and Severe Obstruction ( $\geq 0.46$ ). For NAF, thresholds were set as: Normal ( $\geq 300$  mL/s), Mild Obstruction (200–299 mL/s), Moderate Obstruction (100–199 mL/s), and Severe Obstruction ( $\leq 99$  mL/s). The classification breakdown is presented in Table 3.

Based on the above classification, patients were categorised according to their NAR and NAF values in the sitting position, and the changes in NAR and NAF between the sitting and supine positions for each subject were calculated and tabulated in Table 4.

From the classification:

- For NAR, 82.61% of patients had normal resistance, while 3.48% had severe obstruction in the sitting position.
- For NAF, 21.74% of patients had normal airflow, and 40% were classified with severe obstruction in the sitting position.

To assess the correlation between the degree of obstruction and changes in NAR and NAF, Kruskal-Wallis test for group comparisons and Spearman's correlation for rank-based relationships analysis were used.

Kruskal-Wallis Test Results:

- NAR Change vs. Classification:  $p=0.0013$  (Significant)
- NAF Change vs. Classification:  $p=0.5943$  (Not Significant)

Spearman Correlation:

- NAR Sitting vs. Change:  $r=-0.303$ ,  $p=0.001$  (Significant negative correlation)
- NAF Sitting vs. Change:  $r=-0.023$ ,  $p=0.807$  (No significant correlation)

Correlation analysis revealed:

**NAR:** There is a significant relationship between the degree of nasal obstruction (based on sitting position) and changes in NAR with positional changes, as confirmed by the Kruskal-Wallis test, and a statistically significant negative Spearman correlation between sitting NAR values and positional changes (Spearman's  $\rho = -0.42$ ,  $p < 0.001$ ). This suggests that patients with higher baseline NAR in the sitting position tend to show greater increases in resistance when moving to the supine position. This finding underscores the clinical implication that patients with higher initial NAR are more likely to experience notable changes in resistance when transitioning between positions. This highlights the importance of evaluating baseline conditions in clinical settings.

**Table 3. Severity of nasal obstruction based on NAR and NAF.**

Obstruction Degree	NAR (sitting position)	NAF (sitting position)
Normal	$\leq 0.25$	$\geq 300$
Mild Obstruction	0.26–0.35	200–299
Moderate Obstruction	0.36–0.45	100–199
Severe Obstruction	$\geq 0.46$	$\leq 99$

**Table 4. Classification of patients based on the degree of nasal airway obstruction**

Obstruction Degree	Number of patients (NAR)	Number of patients (NAF)
Normal	95 (82.61%)	25 (21.74%)
Mild Obstruction	15 (13.04%)	22 (19.13%)
Moderate Obstruction	1 (0.87%)	22 (19.13%)
Severe Obstruction	4 (3.48%)	46 (40%)

**NAF:** There is no significant relationship between the degree of nasal obstruction and changes in NAF with positional changes, based on both tests. This implies that the airflow variations may not strongly depend on the sitting position classification and changes in NAF with position are less dependent on baseline airflow, suggesting positional effects may be influenced by other factors like anatomical variations or mucosal dynamics.

## DISCUSSIONS

The current study revealed a deterioration in nasal permeability when transitioning from a seated to a lying-down position in individuals diagnosed with OSA. In our patients with OSA, we observed that total NAR increases on lying down, consequently total NAF reduces.

Previous studies involving both healthy individuals and those with different nasal pathologies, such as chronic nasal obstruction and allergic rhinitis, have demonstrated an increase in total nasal airway resistance (NAR) when changing to the supine position<sup>1,2,7,11-14,24</sup>. By using acoustic rhinomanometry, it was well proven that intranasal cross-sectional area reduces on lying down in healthy subjects<sup>3,24,25</sup>.

The underlying physiology of nasal congestion on decubitus remains unclear. A review of the literature has identified three disorders that may contribute to the occurrence of nasal congestion. These disorders, individually or in concert with one another, could influence the development of nasal congestion:

- **Venous Stasis Hypothesis:** This hypothesis is supported by the observation that, in the erect position, the pressure within the jugular vein is nearly zero, whereas it increases from 4.5 mmHg to 11 mmHg when lying down. In line with this, nasal resistance also increases after compression of the jugular vein<sup>1,26</sup>.
- **Baroreceptor-Mediated Reflex Hypothesis:** Studies have demonstrated that applying unilateral pressure to the axillary region or the lateral side of the body induces ipsilateral nasal congestion and contralateral decongestion. This suggests that a neural reflex is mediated by pressure receptors<sup>27</sup>.
- **Sympathetic Withdrawal and Parasympathetic Preponderance Hypothesis:** Sympathetic withdrawal and a predominance of parasympathetic autonomic nervous system activities during a positional change from sitting to a supine position, results in vascular dilation of the nasal mucosa<sup>14</sup>.

On the contrary, some studies have reported the number of patients who did not exhibit any significant change in nasal resistance in the supine position<sup>28,29</sup>. This suggests that a reduction in nasal compliance is not a universal disorder and that there must be other factors contributing to the effect of recumbency on nasal resistance apart from

the change in body posture.

While the above hypotheses explain the increase in nasal resistance, variability in individual response, such as the asymmetric changes observed in our study, suggests that other factors (e.g., natural variations in nasal anatomy, nasal cycle dynamics, or differential responses to positional changes) may also play a role. Further imaging studies (e.g., CT or MRI) may help elucidate the underlying causes.

However, in studies conducted among OSA patients, the results are conflicting, and most of the studies utilised classical rhinomanometry<sup>2,10,28,30</sup>. In our study, the nasal resistance significantly increased, when changing from the sitting to the supine position. De Vito et al., in their study on patients with OSA, discovered that 31% of individuals with normal basal nasal resistance developed pathological nasal resistance when in a recumbent position<sup>10</sup>. Hiyama et al.<sup>30</sup> studied nasal resistance in the four positions: sitting erect, 30° and 60° dorsally reclined, and supine. They observed a progressive decrease in nasal patency from the sitting erect position to the supine position, with the greatest difference seen between the 60° reclined and supine positions<sup>30</sup>. Karlsson et al. observed that increased nasal obstruction while sitting predicts total airway collapse while lying down<sup>24</sup>.

Contrary to our findings and other similar studies, Hellgren et al.<sup>15</sup> noticed that the normal decrease in nasal patency following a change in body position from sitting to supine was absent in patients with OSA. They postulated that this absence of change in nasal patency in OSA patients in supine position could be related to increased sympathetic neurovascular activity, as OSA patients have increased stress levels that could affect the nose via circulating adrenalin and noradrenalin<sup>12,15</sup>.

In OSA patients, the nasal airway contributes more than 50% to the upper airway resistance<sup>17,18</sup>. In community studies among a large cohort of OSA patients, it was shown that 65% of non-allergic rhinitis patients experienced nasal obstruction symptoms at night<sup>31</sup>, 65% of OSA patients had increased nasal congestion at least once per week, 35% of patients had at least 3 times a week<sup>6</sup>. This was associated with increased daytime sleepiness and reduced mental health quality-of-life score due to the micro arousals happening at night<sup>6</sup>.

The observations from our study are of utmost importance in OSA patients for whom nocturnal nasal breathing is crucial. According to the Starling resistor Model, an increase in nasal resistance can augment upper airway collapse in patients with OSA. Solomon et al. in their study observed that many participants began mouth breathing within seconds after becoming supine which can worsen OSA<sup>32</sup>. Similarly, various other studies have also shown a positive correlation between objective nasal obstruction measurement and

AHI, respiratory distress index (RDI) and an inverse correlation between nasal volume and AHI as well as oxygen dissociation index (ODI) in OSA patients<sup>5,12</sup>.

Nasal resistance has also an important role in patient acceptance and compliance to OSA treatment options. Hiyama et al.<sup>30</sup> found that nasal resistance increases with the degree of decubitus, and a 30° postural change from the supine position can dramatically increase nasal patency and reduce the severity of OSA. Sugiura et al.<sup>33</sup> have shown that for each 0.1 Pa/cm<sup>3</sup>/sec increase in nasal resistance the odds ratio of non-acceptance of CPAP therapy increases 1.48-fold. Friedman et al. showed that a reduction in nasal resistance can lower CPAP pressure levels, improving patient compliance with PAP therapy<sup>34</sup>. He emphasised the role of prephase nasal surgery in patients with OSA, to facilitate other treatment options in OSA. In studies by Zeng et al.<sup>35</sup> and Marklund et al.<sup>36</sup>, nasal resistance was identified as one of the most important predictive factors of oral appliance response. Higher levels of NAR may negatively impact treatment outcomes with mandibular advancement devices<sup>35,36</sup>.

Nakata et al.<sup>37</sup> have shown that reduction in NAR by nasal surgeries improves acceptance of CPAP, sleep quality, daytime somnolence and overall QoL. They observed a reduction in apnea-hypopnea duration but no significant improvement in AHI. A recent meta-analysis and a large scale multicentric study also showed significant improvement in AHI, and QOL in patients undergoing prephase nasal surgery<sup>38,39</sup>. Compared with placebo, topical nasal decongestants and corticosteroids have also shown significant improvement in various sleep parameters including AHI, by reducing the nasal congestion and NAR<sup>40,41</sup>.

In summary, our study using 4-phase positional rhinomanometry confirms the effect of decubitus position on nasal compliance, specifically its reduction when going from a seated position to a lying down position. This change is more pronounced in patients with high nasal resistance in the sitting position. Medical or surgical management should be considered to reduce the nasal airway resistance in OSA patients with nasal pathologies prior to considering other OSA treatment options.

#### **Limitations of the study**

In the management of obstructive sleep apnea (OSA), nasal resistance throughout the entire night is crucial, not just during the first few minutes after lying down. Since no follow-up evaluations were conducted on the patients, uncertainty remains regarding the duration and reversibility of the increase in nasal resistance caused by decubitus.

The complexities of nasal physiology encompass a multifaceted interplay between internal and external factors influencing mucosal thickness and nasal airway patency. Though we have tried to finish the studies within 20 minutes to eliminate the effect of nasal cycle, the normal nasal physiology is still not understood clearly and we may have confounding results due to the normal nasal cycle.

## **CONCLUSIONS**

From our observations and various other studies, it is clear that total nasal airway resistance increases and nasal airflow decreases when lying down. Changing postures significantly contributes to the source of variation in nasal cavity patency. This finding is of utmost importance to snorers and sleep apnea patients, as more than fifty percent of upper airway resistance is attributed to the nose. Any increase in upstream resistance can cause downstream collapse of the pharyngeal airway in OSA patients. Therefore, addressing the reduction in nasal airway resistance, either through medication or surgery, can help improve sleep quality in OSA patients.

4-Phase positional rhinomanometry should be performed to diagnose upper airway collapse in the supine position as part of the OSA evaluation.

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**Ethical approval:** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional ethical committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The Institutional Ethical Committee and Review Board of AIG Hospitals, Hyderabad, Telangana, India has approved the study protocol.

**Informed consent:** Informed consent was obtained from all individual participants included in the study.

**Data availability:** The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

**Contribution of authors:** Sanu P Moideen, Srinivas Kishore Sistla conceived the presented idea, developed the theory, collected the data and performed the computations. Sabu Abdul Hameed Noorjehan, Razal Mohammed Sheriff helped in manuscript drafting. Subina Beegum Samad verified the analytical methods and proof reading.

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