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A Cross-Sectional Study of SNOT-22 and PSQI Profiles in Allergic Rhinitis: Sleep Impairment and Mental Health Burden in Polluted Urban India

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ABSTRACT

Introduction: Allergic rhinitis (AR) significantly affects sleep quality and psychological well-being, particularly in polluted urban regions of India where fine particulate matter ($PM_{2.5}$) levels frequently exceed WHO safety limits. The present study aimed to evaluate the burden of AR on sleep and mental health using standardised clinical scales in an urban population from Mathura.

Methodology: A cross-sectional analysis was conducted on 200 adults aged 18-60 years diagnosed with persistent AR attending an ENT OPD. Individuals with asthma, chronic respiratory diseases, or psychiatric comorbidities were excluded. Participants completed the Sino-Nasal Outcome Test-22 (SNOT-22) and Pittsburgh Sleep Quality Index (PSQI) questionnaires. Subgroup comparisons were performed between individuals exposed to high versus moderate ambient pollution levels.

Results: Most participants were young adults (63% aged 18-35 years). Poor sleep quality (PSQI >5) was reported by 72% of respondents, with 41% experiencing difficulty initiating sleep and 43% reporting frequent nighttime awakenings (≥3 times per week). The SNOT-22 identified nasal blockage in 73%, sleep-related complaints in 68%, and psychological distress- such as frustration, low mood, or poor concentration in 53–61% of participants. Exposure to higher pollution levels was associated with greater symptom severity for sleep (78% vs 51%), psychological domains (65% vs 40%), and overall PSQI impairment (82% vs 58%).

Conclusion: Persistent AR in polluted urban environments exerts a notable multisystem burden on both sleep and mental health. These findings emphasize the need for integrated management approaches combining nasal therapy, pollution control, and regular screening for psychological distress in resource-constrained settings.

Keywords: Allergic Rhinitis, SNOT-22, PSQI sleep quality, Air pollution India

INTRODUCTION

Allergic rhinitis (AR) is now recognised as one of the most common chronic respiratory disorders in India, with community-based data indicating that roughly one-fifth to one-third of the population experiences allergic airway symptoms at some point in life. Urban regions bear a disproportionate share

of this burden: rapid industrialisation, dense traffic, and changing lifestyles have been accompanied by a clear upward trend in AR prevalence over recent decades. In large cities and peri-urban belts, the proportion of individuals with AR often exceeds that seen in rural settings, reflecting higher exposure to airborne particulates, gases, and indoor allergens. These Indian observations mirror global patterns but are amplified by the intensity and persistence of air pollution in many metropolitan areas, where $PM_{2.5}$ levels commonly surpass both World Health Organisation (WHO) guideline values and national standards.[1-3]

Multiple environmental drivers converge to create a particularly hostile airway milieu in urban India. Fine particulate matter ($PM_{2.5}$) from vehicular exhaust, industrial emissions, and biomass or crop-residue burning penetrates deep into the upper and lower respiratory tract, inducing oxidative stress, epithelial damage, and heightened mucosal permeability. Seasonal agricultural burning and temperature inversions frequently trap these pollutants close to the ground, leading to prolonged episodes of smog that aggravate nasal symptoms in susceptible individuals. Residents from lower socioeconomic strata are especially vulnerable; they often live in poorly ventilated dwellings near busy roads and spend extended periods outdoors for work, thereby sustaining continuous exposure to irritants and aeroallergens. Against this background, AR in India is not merely a nuisance symptom complex but a chronic inflammatory condition with systemic repercussions for sleep, mood, and daily functioning.[1,2]

The clinical manifestations of AR- sneezing, rhinorrhoea, nasal obstruction, and itching translate directly into nocturnal discomfort.[3] To capture the multifaceted impact of AR, disease-specific and generic patient-reported outcome measures are increasingly used in both clinical practice and research.[4,5] Persistent nasal blockage and post-nasal drip interfere with airflow during sleep, promote mouth breathing, and result in frequent awakenings or prolonged sleep latency.[5,6] The 22-item Sino-Nasal Outcome Test (SNOT-22) is one of the most widely validated instruments in rhinology and has been specifically evaluated in AR populations. It spans multiple domains including nasal symptoms, ear/facial symptoms, sleep function, and psychological distress. Sleep-related items (questions 7-9) enquire about trouble falling asleep, nocturnal awakenings, and lack of restful sleep, while psychological items (questions 17-19) address feelings of embarrassment, frustration, and sadness or depression. Studies in persistent AR have demonstrated that higher SNOT-22 scores are associated with worse general quality of life and poor disease control, and that reductions of approximately 6-11 points correspond to clinically meaningful improvement after treatment.[4] Importantly, elevated scores in the psychological and sleep subdomains often track with independently measured anxiety and depressive symptoms, reinforcing the concept of AR as a condition with significant emotional and cognitive consequences.[4,5,7]

Observational studies and meta-analyses using the Pittsburgh Sleep Quality Index (PSQI) consistently show that between 70% and 85% of patients with AR have poor sleep (global PSQI score >5), compared with roughly 25-35% among individuals without allergic disease.[5,8] Poor sleep quality in AR has been linked not only to daytime fatigue and cognitive difficulties but also to higher rates of anxiety and depressive symptoms, suggesting a bidirectional relationship between nasal inflammation, sleep disruption, and mental health.[5,9]

Despite this evidence, the interplay between air pollution, AR severity, sleep quality, and mental health remains under-characterised in the Indian context.[1,3,6] Much of the existing Indian literature has focused on prevalence estimates, risk factors, and coexisting asthma rather than on detailed symptom profiles and quality-of-life

metrics.[1,3,7] Surveys such as the CARAS study highlight the frequent coexistence of AR and asthma, reported in a substantial proportion of Indian patients and underline the role of indoor dust and other aeroallergens as major sensitising agents.[7] However, relatively few studies have systematically quantified sleep impairment and psychological burden in AR using validated tools like SNOT-22 and PSQI, particularly in socioeconomically disadvantaged urban groups exposed to sustained high pollution. International data and ARIA recommendations suggest that uncontrolled AR, especially when combined with environmental triggers, contributes to fragmented sleep, daytime fatigue, and poor mental health, yet such multidimensional assessment has rarely been applied in Indian AR cohorts.[3,5,7,9]

Mathura, a mid-sized city in northern India, exemplifies this scenario, with National Air Quality Index reports from the Central Pollution Control Board (CPCB) frequently flagging “poor” to “very poor” categories driven by highway traffic, industrial activity, and seasonal biomass burning.[2,10] At the same time, a substantial proportion of its population belongs to low- or lower-middle-income groups who depend on public hospitals for ENT care and may not seek or receive systematic evaluation of sleep and mental health symptoms.[1,3] There is a clear need for pragmatic, low-cost assessment strategies that can be implemented in busy outpatient settings to identify AR patients at risk of significant sleep disruption and psychological morbidity.[4,5,9]

Against this background, the present cross-sectional study was undertaken in a tertiary ENT outpatient department (OPD) in Mathura to characterise the burden of sleep and mental health problems among adults with persistent AR. Using the SNOT-22 and PSQI, this study aims to: (i) estimate the prevalence of poor sleep (PSQI >5) and elevated psychological burden (SNOT-22 psychological items >2); (ii) describe patterns of nasal and sleep-related symptoms; and (iii) explore associations between self-reported pollution exposure and these outcomes in an urban Indian cohort. By integrating disease-specific (SNOT-22) and sleep-focused (PSQI) tools within a pollution-aware framework, the study seeks to generate evidence that can inform targeted screening, counselling, and management pathways suitable for resource-limited ENT clinics, in line with ARIA recommendations to address both symptom control and quality of life.

MATERIALS & METHODS

Study Design and Setting: This investigation employed a cross-sectional observational approach. It was conducted at the OPD of Otorhinolaryngology (ENT) department of a tertiary care hospital in Mathura, Uttar Pradesh, India. The study spanned one year from January 2025 to January 2026. The study centre represents several north India's urban pollution challenges- heavy vehicular traffic along national highways, proximity to the Yamuna River, and seasonal agricultural stubble burning contribute to persistently elevated air quality index (AQI) readings, often categorised as “poor” or “very poor”. This setting allowed examination of allergic rhinitis (AR) manifestations in a real-world, high-exposure environment typical of semi-industrialised cities with limited air quality infrastructure.

The cross-sectional design facilitated efficient data gathering without longitudinal follow-up, aligning with resource constraints in busy ENT clinics while enabling prevalence estimates and subgroup comparisons. All procedures adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for transparency and reproducibility.

Participant Selection Criteria: Eligible participants comprised consecutive adults aged 18 to 60 years presenting to the ENT OPD with symptoms consistent with persistent AR, as defined by the Allergic Rhinitis and its Impact on Asthma (ARIA)

2016 guidelines. Persistent AR required nasal symptoms- rhinorrhea, sneezing, nasal itch, or obstruction- for more than one year, occurring at least four days per week and four consecutive weeks.[9] Additional inclusion mandates included residency in Mathura district for at least six months to ensure meaningful local pollution exposure, willingness to complete self-administered questionnaires, and a body mass index (BMI) within the normal range of 18.5-22.9 kg/m² (Asian-specific cutoff to minimise obesity-related sleep confounds).[11]

Exclusions were rigorously applied to isolate AR-specific effects on sleep and mental health. Patients with acute upper respiratory tract infections (within two weeks), nasal polyps (confirmed via nasal endoscopy), diagnosed asthma or obstructive sleep apnea (OSA; per history or prior polysomnography), current or past smoking (≥100 cigarettes lifetime), substance use disorders, psychiatric illnesses (e.g., depression, anxiety per ICD-11), or use of sedating medications (e.g., first-generation antihistamines, benzodiazepines) were ineligible. These criteria minimised confounding from comorbidities known to independently impair sleep architecture or sino-nasal function, ensuring attribution to AR and ambient pollution.

Sample Size Determination: A convenience sample of 200 participants was targeted. The sample size was determined based on feasibility, availability of cases during the study period, and comparison with similar previously published studies from AR literature.[5]

Data Collection Procedures: Following a brief nasal examination (anterior rhinoscopy) to confirm AR absence of structural anomalies, trained ENT residents obtained written informed consent in Hindi or English. Questionnaires were administered by a trained ENT resident in a quiet waiting area (average 10–12 minutes).

The Sino-Nasal Outcome Test-22 (SNOT-22) employed a 0-5 Likert scale per item (0=not problematic, 5=problematic/severe), yielding a total score of 0-110. Subscales focused on sleep dysfunction (questions 7-9: trouble sleeping, nocturnal awakenings, poor rest) and psychological impact (questions 17-19: embarrassment, frustration, depression), with mean scores >2 denoting moderate-severe burden.[4]

Pittsburgh Sleep Quality Index (PSQI) assessed one-month sleep patterns across seven components (latency, duration, efficiency, disturbances, medication, daytime dysfunction, quality), each scored 0-3, summed to a global score of 0-21 (>5=poor sleep; sensitivity 89.6%, specificity 86.5%).[8]

Pollution exposure was categorised via self-report proxy measures, validated against CPCB air quality index (AQI)[10] (i) hazy/polluted days perceived ≥15 per month; (ii) outdoor symptom worsening (yes/no); (iii) residence within 500 meters of major roads/traffic hubs. High exposure required ≥2 affirmative responses; low exposure, ≤1.

Sociodemographic details captured age groups (18–35, 36–60 years), gender, occupation (housewife, semiskilled, professional), monthly household income (<Rs.50,000, Rs.50,000-1,00,000, >Rs.1,00,000), education (below matric, matric, graduate, postgraduate), marital status, and family atopy history (at least one first-degree relative with AR/asthma).

Ethical Considerations: The study protocol received approval from the Institutional Review Board/Ethics Committee. The study was conducted in accordance with established ethical guidelines. Participants received verbal/written study information emphasising voluntary participation, confidentiality, and right to withdraw without affecting care. Written informed consent was obtained from all participants.

Study Outcomes and Hypotheses: Primary outcomes measured prevalence of poor sleep (PSQI global >5) and psychological burden (SNOT-22 psychological mean >2). Secondary outcomes included domain-specific percentages (e.g., SNOT-22 nasal blockage ≥3), sleep component profiles, and

pollution-exposure associations (e.g., OR for PSQI >5 in high vs. low groups). Exploratory aims examined sociodemographic modifiers.

Hypotheses predicted: (i) ≥70% PSQI >5 overall; (ii) 50–60% SNOT-22 psychological burden; (iii) 1.5–2-fold higher impairment in high-pollution subgroups, reflecting synergistic AR-pollution effects.

Statistical Analysis

Descriptive statistics were used to summarize all study variables, with categorical data presented as frequencies and percentages. Comparisons between pollution exposure subgroups (high and low) were performed using the chi-square test. A p-value of less than 0.05 was considered statistically significant. The proportion of missing data was less than 5% across variables; therefore, a complete-case analysis approach was adopted for statistical evaluation.

RESULTS

Among the 200 patients with allergic rhinitis, nearly two-thirds were young adults aged 18–35 years (63%), while 37% were between 36 and 60 years. There was a slight male predominance, with 53% males and 47% females. Most participants were married (73%), with 22% unmarried and 5% divorced or widowed. The majority belonged to lower-income households, with 74% reporting a monthly family income below Rs. 50,000, 22% between Rs. 50,000 and 1,00,000, and only 4% above Rs. 1,00,000. Educational attainment was generally low to moderate: 20% were illiterate and 23% had education below matriculation, while 31% had studied up to matriculation and 16% up to higher secondary; only 7% were graduates and 3% postgraduates. In terms of occupation, housemakers (34%) and semiskilled workers (30%) formed the largest groups, followed by skilled workers (11%), students (9%), businesspersons (3%), and farmers (1%), with 12% engaged in other occupations. A positive family history of atopy was present in 40% of patients, while 60% reported no such history.

Table 1. Sociodemographic Characteristics of Patients with Allergic Rhinitis (n=200).

Characteristics		**% (n)**
Age	18-35 years	63 (126)
	36-60 years	37 (74)
Gender	Males	53 (106)
	Females	47 (94)
Marital Status	Unmarried	22 (44)
	Married	73 (146)
	Divorced/Widow	5 (10)
Family Income per Month	Rs. <50000	74 (148)
	Rs. 50000-100000	22 (44)
	Rs. >100000	4 (8)
Education	Illiterate	20 (40)
	Below Matriculation	23 (46)
	Matriculate	31 (62)
	Higher Secondary	16 (32)
	Graduate	7 (14)
	Postgraduate	3 (6)
Occupation	Student	9 (18)
	Housemaker	34 (68)
	Semiskilled	30 (60)
	Skilled	11 (22)
	Business	3 (6)
	Farmer	1 (2)
	Other	12 (24)
Family history of atopy	Yes	40 (80)
	No	60 (120)

On the PSQI, 41% of patients (n=82) reported trouble falling asleep at least twice per week, and 43% (n=86) woke up at night three or more times per week. Difficulty initiating sleep was further reflected by 35% (n=70) needing more than 30 minutes to fall asleep. Overall, 72% of the cohort (n=144) had a global PSQI score greater than 5, indicating poor sleep quality in nearly three-quarters of allergic rhinitis patients.

Table 2. Sleep Problems (PSQI)	
PSQI Question	**% Affected (n)**
Trouble falling asleep (≥2x/week)	41 (82)
Wake up at night (≥3x/week)	43 (86)
Need >30 min to fall asleep	35 (70)
Poor sleep overall (PSQI>5)	72 (144)

On the SNOT-22, nasal blockage was the most frequently reported symptom, affecting 73% of patients (n=146). Runny nose was present in 65% (n=130), while sleep problems related to nasal symptoms were reported by 68% (n=136). More than half of the cohort (54%, n=108) also complained of feeling tired or fatigued, indicating a substantial impact of nasal disease on daytime functioning.

Table 3. Nasal Symptoms (SNOT-22)	
Symptoms	**% Affected (n)**
Nasal blockage	73 (146)
Runny nose	65 (130)
Sleep problems	68 (136)
Tired/fatigued	54 (108)

On the mental health domain of SNOT-22, 53% of patients (n=106) reported feeling depressed. Feelings of embarrassment were present in 45% (n=90), while frustration or irritability was noted by 56% (n=112). Poor concentration was the most frequent psychological complaint, affecting 61% of the cohort (n=122), highlighting a prominent cognitive and emotional burden among allergic rhinitis patients.

Table 4. Mental Health Burden (SNOT-22)	
Problems	**% Affected (n)**
Feeling depressed	53 (106)
Embarrassed	45 (90)
Frustrated/irritable	56 (112)
Poor concentration	61 (122)

Patients residing in high-pollution areas had a markedly greater burden of sleep and mental health problems than those in low-pollution zones. Poor sleep (PSQI >5) was reported by 82% (n=98) of the high-pollution group compared with 58% (n=46) in the low-pollution group, with a 95% confidence interval (CI) for the difference of 8.24% to 39.68% and a statistically significant p value of 0.0022. Similarly, sleep problems on the SNOT-22 were more frequent in the high-pollution subgroup (78%, n=94) than in the low-pollution subgroup (51%, n=41; 95% CI 9.69%–43.38%, p=0.0017). Mental health burden (SNOT-22 psychological items) was also higher in high-pollution residents (65%, n=78) compared with those in low-pollution areas (40%, n=32), with a 95% CI of 4.59% to 42.84% and p=0.0164, indicating a significant association between higher pollution exposure and greater psychological morbidity.

Table 5. Pollution Subgroups and Burden				
Parameter	**High Pollution (n=120) %(n)**	**Low Pollution (n=80) %(n)**	**95% CI**	**P value**
Poor sleep (PSQI>5)	82 (98)	58 (46)	8.24% to 39.68%	p=0.0022
Sleep problems (r-SNOT)	78 (94)	51 (41)	9.69% to 43.38%	p=0.0017
Mental burden (r-SNOT)	65 (78)	40 (32)	4.59% to 42.84%	p=0.0164

DISCUSSION

This study provides a detailed snapshot of the clinical, sleep, and psychological burden of AR among adults attending a tertiary ENT clinic in a polluted urban setting in North India. The sociodemographic pattern, with a predominance of young to middle-aged adults, suggests that AR in such environments disproportionately affects individuals at the most economically productive stages of life. These findings are consistent with Indian epidemiological work indicating that AR frequently manifests and peaks in early and middle adulthood, a period characterised by occupational and family responsibilities as well as high exposure to outdoor and indoor pollutants. The high proportion of patients from lower income households and with limited educational attainment underlines the intersection of environmental and socioeconomic vulnerability, where reduced access to air-conditioned workplaces, cleaner housing, and specialist care may compound disease burden.

A notable proportion of participants reported a positive family history of atopy, supporting a genetic predisposition to allergic airway disease. This aligns with established concepts of AR as a complex trait in which genetic susceptibility-reflected in familial clustering of AR, asthma, and other atopic conditions interacts with environmental exposures such as traffic related air pollution, biomass smoke, and indoor allergens. In this cohort, chronic exposure to high levels of particulate matter and gaseous pollutants in Mathura, as reflected in national air quality data and local AQI classifications, likely acts as a continuous trigger on this atopic background. The combination of host predisposition and sustained irritant load provides a biologically plausible explanation for persistent nasal symptoms, sleep disruption, and psychological distress in these patients.[1]

From a clinical standpoint, the pattern of symptoms observed in this study resonates with the ARIA framework, which describes AR as a chronic inflammatory disorder with substantial impact on daily functioning and quality of life when not adequately controlled.[9] The dominance of nasal blockage and rhinorrhoea, coupled with high SNOT-22 scores in sleep and psychological domains, signals that the disease in this cohort is not confined to intermittent, mild symptoms but often represents persistent, moderate-to-severe AR. This is in line with previous Indian reports highlighting that many patients present late or remain partially treated, often self-managing with over-the-counter medications and lacking sustained guideline-based therapy.[2]

The sleep findings are particularly striking. Nearly three quarters of the patients met the PSQI criterion for poor sleep (global score >5), and substantial proportions reported trouble initiating sleep, frequent nocturnal awakenings, and prolonged sleep latency. These results echo the systematic review and meta-analysis by Liu et al., which demonstrated that AR is consistently associated with higher odds of insomnia, non-restorative sleep, and daytime dysfunction compared with non-allergic controls.[5] Similarly, work in chronic rhinitis populations has shown that nasal obstruction, rhinorrhoea, and postnasal drip correlate with altered sleep architecture-reduced slow-wave sleep and increased arousals on polysomnography.[5,6] The nearly parallel prevalence of PSQI-defined poor sleep (72%) and SNOT-22 sleep items reporting moderate to severe problems (68%) in this study suggests a close link between active nasal disease and sleep disturbance. Rather than being separate problems, symptom driven nocturnal discomfort and dysfunctional sleep appear to be interwoven manifestations of the same underlying inflammatory process.[3-6]

Mechanistically, nasal blockage increases upper airway resistance, particularly in the supine position, promoting mouth breathing and predisposing to snoring and micro arousals. Persistent rhinorrhoea and postnasal drip can cause discomfort, throat

clearing, and coughing at night, further fragmenting sleep and prolonging sleep onset. In our cohort, more than half of the patients also reported daytime tiredness and fatigue on SNOT-22, which likely represent downstream consequences of this chronic nocturnal disruption. These daytime symptoms are clinically important because they are associated with reduced work productivity, impaired academic performance, and decreased participation in social and family roles.[5,6] Indian AR and combined rhinitis-asthma surveys have similarly reported absenteeism, presenteeism, and school performance deficits in symptomatic patients, underscoring the broader societal cost of uncontrolled AR.[7]

Beyond physical symptoms, the study highlights a substantial psychological burden. Over half the participants endorsed SNOT-22 items reflecting low mood, embarrassment, irritability, and difficulty concentrating. The prominence of poor concentration (61%) and frustration or irritability (56%) suggests that AR in this context is experienced not only as a physical nuisance but also as an emotionally taxing condition that interferes with cognitive performance and daily interactions. These findings are consistent with observational and cross-sectional studies reporting higher rates of anxiety and depressive symptoms in patients with persistent or severe AR, especially when accompanied by poor sleep and comorbid asthma. Sleep disturbance is a recognised risk factor for mood and anxiety disorders, and chronic inflammatory states have been linked to altered neurotransmitter function and hypothalamic–pituitary–adrenal axis dysregulation, providing plausible biological pathways linking nasal disease, sleep, and psychological morbidity.[2-5]

The coexistence of AR and asthma, although not directly assessed here due to exclusion criteria, is highly relevant when interpreting these mental health findings. The CARAS survey documented that a significant proportion of Indian asthma patients also have AR, and that coexistent disease is associated with greater symptom burden and reduced quality of life. While we intentionally excluded diagnosed asthma to focus on isolated AR, many participants likely share the same atopic and environmental risk factors that drive the rhinitis-asthma continuum. ARIA emphasises that AR and asthma should be considered part of a single airway disease entity, and that poor control of one component can adversely affect the other. Even in the absence of diagnosed asthma, the psychological strain of living with persistent nasal disease, disrupted sleep, and worries about respiratory health may contribute to the elevated SNOT-22 mental domain scores observed in this cohort.[2,7]

The pollution stratified analysis represents one of the most important contributions of this study. Patients classified as living in high pollution zones, based on proximity to major roads, self-reported frequency of hazy days, and outdoor symptom worsening had substantially higher prevalence of poor sleep, sleep related SNOT-22 complaints, and psychological burden than those residing in relatively lower pollution areas. The differences were not only statistically significant but also clinically meaningful, often exceeding 20 percentage points for key outcomes. These findings complement national and international data linking elevated long-term exposure to particulate matter and traffic related air pollutants with increased respiratory symptoms, higher use of healthcare resources, and poorer quality of life.[1,2]

From a pathophysiological perspective, chronic inhalation of fine particulates and gaseous pollutants can upregulate inflammatory pathways in the nasal mucosa, enhance allergen penetration, and augment the Th2 (T-helper type 2)-skewed immune response characteristic of atopic disease. Repeated or sustained exposure may therefore intensify nasal congestion and rhinorrhoea, exacerbating sleep disruption and subsequent fatigue. Furthermore, emerging evidence suggests that air

pollution may have direct neuroinflammatory and neuropsychiatric effects, contributing to anxiety, depressive symptoms, and cognitive deficits, particularly in vulnerable populations. While our study was not designed to disentangle these direct effects from the indirect impact mediated through AR severity, the consistent pattern of higher mental burden in high pollution residents suggests that environmental exposures likely amplify both physical and psychological aspects of disease.[5,6,9]

The role of environmental control in AR management is emphasised in ARIA guidelines, which advocate for allergen and irritant avoidance, including reduction of exposure to tobacco smoke, occupational irritants, and outdoor pollutants where feasible.[9] However, in many Indian urban contexts, individual level control over ambient air quality is limited, and patients may be unable to relocate or substantially modify their work and travel patterns. Our findings therefore highlight the need to integrate clinical management strategies with broader public health and policy measures. Strengthening air quality monitoring, disseminating real-time AQI information, implementing pollution control regulations, and promoting cleaner transport and energy solutions are crucial to reducing the upstream drivers of AR exacerbation. At the same time, clinicians can advise patients on practical steps such as avoiding peak traffic periods, using masks during high pollution days, ensuring adequate indoor ventilation and cleanliness, and optimising pharmacological control of nasal inflammation.

The strong association between poor sleep and nasal/mental symptoms also suggests several actionable implications for routine clinical practice. First, simple sleep screening using the PSQI or a brief questionnaire can be incorporated into ENT outpatient visits without major time or cost burdens. Identifying patients with PSQI >5 allows targeted counselling on sleep hygiene, timing of intranasal medications, and management of nocturnal symptoms. Second, SNOT-22, which is already widely used for sinonasal disease, can serve as a dual tool for monitoring both nasal and psychological domains, helping clinicians recognise patients who may benefit from further mental health evaluation or support. Third, given the high prevalence of fatigue, irritability, and concentration difficulties, it would be reasonable to normalise discussion of emotional wellbeing in AR consultations, and to consider brief screening instruments for anxiety and depression in patients with significant SNOT-22 mental scores.[4,8]

Our findings also underscore the importance of earlier and more aggressive control of AR in polluted urban settings. Intranasal corticosteroids and second-generation antihistamines remain the cornerstone of pharmacological management for moderate-to-severe AR, with proven efficacy in reducing nasal symptoms and improving quality of life. In patients with prominent sleep disturbance, optimising dose timing (for example, evening dosing of intranasal corticosteroids and/or non-sedating antihistamines) and addressing nasal obstruction with saline irrigations or short-term decongestants under supervision may help improve nocturnal airflow. For those with persistent sleep complaints despite adequate AR control, referral for sleep evaluation- including consideration of obstructive sleep apnoea where indicated could be warranted. Multidisciplinary collaboration between ENT specialists, pulmonologists, sleep physicians, and mental health professionals may provide the most comprehensive care for complex cases.[3,7,9]

While the present study adds important information, it should be interpreted within its methodological limitations. The cross-sectional design precludes conclusions about causality or temporal relationships among pollution exposure, AR severity, sleep disturbance, and mental health outcomes. Convenience sampling from a single tertiary care centre may introduce selection bias; patients presenting to ENT

clinics may have more severe or persistent symptoms than those managed in primary care or not seeking treatment, limiting generalisability to the broader community. Pollution exposure classification relied on self-report rather than individual level $PM_{2.5}$ or NO_2 measurements or geo-coded AQI data, raising the possibility of misclassification and dilution of true exposure-response relationships. Furthermore, the study used only questionnaire-based assessments (SNOT-22 and PSQI) without objective sleep studies (such as polysomnography or actigraphy) or formal psychiatric diagnostic interviews, so we cannot rule out unrecognised sleep disorders or mental health conditions that may have influenced scores. Nevertheless, both SNOT-22 and PSQI are well validated, widely used instruments in sinonasal and sleep research, lending credibility to the patterns observed.

Another consideration is the BMI restriction used in this study, which followed WHO Asia-Pacific criteria to focus on normal weight individuals and reduce confounding from obesity related sleep problems. While this strengthens the internal validity of the observed associations between AR, pollution, and sleep, it may underestimate the overall burden of sleep disturbance and psychological symptoms in the general AR population, where overweight and obesity are increasingly prevalent. Future studies should explicitly compare normal weight and overweight/obese AR patients to clarify the additive or interactive effects of adiposity on sleep and mental health in polluted environments.

Looking ahead, several avenues for further research emerge. Longitudinal studies tracking AR patients across seasons and variable pollution levels could help clarify temporal relationships and identify thresholds at which symptom burden and sleep impairment worsen. Incorporating objective air pollution data (from fixed monitoring stations or personal sensors) and objective sleep measures would allow more precise quantification of exposure-response relationships and disentangle direct neurocognitive effects of pollution from those mediated by nasal inflammation. Including measures of work productivity, school performance, and healthcare utilisation would provide a more comprehensive picture of the socioeconomic impact of AR-related sleep and mental health problems in low- and middle-income urban settings. Finally, interventional studies evaluating the effects of combined strategies- such as optimised AR pharmacotherapy, sleep hygiene counselling, and simple exposure reduction advice on PSQI, SNOT-22, and mood outcomes would be highly valuable for informing integrated care pathways.

Taken together, these findings highlight that, in polluted urban Indian settings, allergic rhinitis is closely intertwined with sleep disruption and psychological distress, particularly in socioeconomically vulnerable, atopy-prone adults. Recognition of this broader impact should encourage clinicians to routinely enquire about sleep quality and emotional wellbeing in patients with persistent nasal symptoms, and should motivate public health efforts that address upstream environmental drivers alongside individual level treatment.

CONCLUSION

In polluted urban Indian settings, allergic rhinitis appears to be a multi-system condition, extending beyond nasal symptoms to significantly impair sleep and mental well-being. Patients living in high-pollution areas, particularly those with an atopic background, showed the highest burden of poor sleep, SNOT-22 sleep complaints, and psychological distress, indicating a synergistic effect of environmental and host factors. These findings support an integrated management strategy that combines guideline-based pharmacotherapy (such as intranasal corticosteroids and second-generation antihistamines), allergen and irritant avoidance, and structured sleep hygiene counselling. Routine use of brief screening

tools for anxiety and depressive symptoms in ENT clinics may help identify vulnerable patients early and facilitate timely referral to mental health services. At the population level, the observed pollution gradient highlights the need to strengthen air quality monitoring and control, enforcing emission control policies, and operationalizing National Air Quality Index-based public health actions to mitigate respiratory symptoms, improve sleep, and reduce psychological morbidity in urban communities.

Declaration by Authors

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