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ORIGINAL ARTICLE

Comparative Analysis of Anatomical Differences in Upper Airways and Soft Tissues Between Healthy Individuals and Those with Sleep Disorder Patients

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ABSTRACT
Background: Obstructive sleep apnea (OSA) and other sleep disorders are associated with anatomical differences in the upper airway and soft tissues, leading to airway obstruction and breathing difficulties. Identifying these variations can aid in early diagnosis and treatment planning.
Objective: To compare anatomical differences in the upper airway and soft tissues between healthy individuals and patients with sleep disorders.
Study Design and Setting: This was a comparative cross-sectional study conducted at Department of Anatomy DIMC, DUHS Karachi over six months.
Methodology: A total of 140 patients were included, with 70 diagnosed sleep disorder patients and 70 healthy controls. Anthropometric data, cephalometric measurements, and advanced imaging were used to assess airway dimensions, soft tissue thickness, and craniofacial structures. Polysomnographic findings and Mallampati classification were also recorded. Data were analyzed using SPSS, with p-values < 0.05 considered statistically significant.
Results: Patients with sleep disorders had significantly higher BMI (29.6 ± 3.4 kg/m²) and neck circumference (40.1 ± 3.2 cm) compared to controls ($p < 0.05$). Cephalometric analysis revealed reduced posterior airway space, increased soft palate thickness, and larger tongue volume in affected individuals. Imaging findings showed a smaller minimum airway cross-sectional area (95.6 ± 17.2 mm²) and greater lateral pharyngeal wall thickness in sleep disorder patients ($p < 0.05$). Polysomnographic results confirmed worsening oxygen desaturation and reduced sleep efficiency in severe cases.
Conclusion: Significant anatomical differences in airway structures contribute to sleep disorders. Recognizing these variations can improve diagnostic accuracy and guide targeted interventions.
Keywords: Airway dimensions, cephalometric analysis, craniofacial morphology, obstructive sleep apnea, polysomnography, sleep disorders, soft tissue thickness

INTRODUCTION
Sleep disorders, particularly obstructive sleep apnea (OSA), are prevalent conditions that significantly impact an individual's overall health and quality of life. OSA is characterized by recurrent episodes of partial or complete airway obstruction during sleep, leading to disrupted sleep patterns, oxygen desaturation, and excessive daytime sleepiness.[1,2] Structural variations in the upper airway and soft tissues play a crucial role in the pathophysiology of sleep disorders. Differences in craniofacial anatomy, tongue volume, pharyngeal soft tissues, and airway collapsibility contribute to the severity of sleep-related breathing disorders.[3,4] According to epidemiological studies, the prevalence of OSA in the general population is estimated to be between 9% and 38% in different regions.[5] In the United States, approximately 15-30% of males and 10-15% of females are affected by OSA.[6]

The upper airway, comprising the nasal cavity, pharynx, and larynx, is a highly dynamic structure influenced by multiple factors, including skeletal morphology, muscle tone, and fat deposition. In individuals with sleep disorders such as OSA, the upper airway tends to be more collapsible due to reduced neuromuscular control and anatomical narrowing.[7] Literature suggest that patients with sleep disorders often exhibit anatomical abnormalities such as an elongated soft palate, increased tongue volume, retrognathia, and reduced airway dimensions. These structural differences contribute to increased airway resistance and collapse during sleep, predisposing individuals to intermittent hypoxia and sleep fragmentation.[8]

Advanced imaging techniques, including cephalometry, computed tomography (CT), and magnetic resonance imaging (MRI), have been instrumental in identifying anatomical risk factors associated with sleep disorders. Moreover, understanding the anatomical disparities between healthy individuals and sleep disorder patients has significant implications for therapeutic interventions.[9,10] Treatment modalities such as mandibular advancement devices, positive airway pressure therapy, and surgical procedures, including maxillomandibular advancement, are often tailored based on individual anatomical characteristics.

This study aims to provide a comparative analysis of anatomical differences in the upper airways and soft tissues between healthy individuals and those with sleep disorders. By identifying key structural variations, this research will contribute to a better understanding of sleep disorder pathophysiology and facilitate the development of more effective diagnostic and therapeutic approaches.

MATERIALS AND METHODS
This comparative cross-sectional study was conducted at Department of Anatomy DIMC, DUHS Karachi over six months, from January 2023 to June 2023. Ethical approval was obtained from the institutional review board, and written informed consent was taken from all participants before their inclusion in the study. A total of 140 participants were enrolled, comprising 70 healthy individuals and 70 patients diagnosed with sleep disorders, including obstructive sleep apnea (OSA).

Participants were selected using a consecutive sampling technique based on predefined inclusion and exclusion criteria. Individuals aged 18 to 65 years, with no history of craniofacial anomalies, prior upper airway surgeries, or neuromuscular disorders, were included in the study. The sleep disorder group consisted of patients diagnosed with OSA based on polysomnography findings, while the control group comprised healthy individuals without any reported sleep-related breathing disorders. Exclusion criteria included patients with chronic

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respiratory diseases, obesity with a body mass index (BMI) above 35 kg/m², or those on sedatives or muscle relaxants that could alter upper airway muscle tone.

All participants underwent detailed clinical assessments, including anthropometric measurements such as height, weight, BMI, and neck circumference. Craniofacial features, including mandibular position, palatal length, and tongue volume, were evaluated using standardized cephalometric analysis. Three-dimensional imaging techniques, including computed tomography (CT) and magnetic resonance imaging (MRI), were used to assess airway dimensions, soft tissue volume, and pharyngeal space. The minimum cross-sectional airway area, posterior airway space, and soft palate thickness were measured using digital software analysis. All imaging procedures were performed by a trained radiologist to ensure consistency and accuracy. Polysomnography was conducted for sleep disorder patients to confirm OSA diagnosis and severity, based on apnea-hypopnea index (AHI) values. Patients with mild (AHI 5-15), moderate (AHI 15-30), and severe (AHI >30) OSA were categorized accordingly. Airway collapsibility was assessed using dynamic MRI imaging during wakefulness and sleep to evaluate differences in muscle tone and soft tissue behavior. Additionally, Mallampati classification was used to assess oropharyngeal crowding in all participants.

Data were recorded in a structured proforma, and statistical analysis was performed using SPSS version 26. Continuous variables such as airway dimensions and soft tissue thickness were analyzed using independent t-tests, while categorical variables were compared using the chi-square test. A p-value of <0.05 was considered statistically significant.

RESULTS

The demographic and anthropometric analysis revealed that patients with sleep disorders had significantly higher BMI (29.6 ± 3.4 kg/m²) and neck circumference (40.1 ± 3.2 cm) compared to healthy individuals (BMI: 24.1 ± 2.8 kg/m², neck circumference: 35.6 ± 2.4 cm). The mean age was slightly higher in the sleep disorder group (42.7 ± 11.1 years) than in the control group (38.2 ± 10.4 years), with a statistically significant difference (p = 0.041). Gender distribution was comparable between the groups (p = 0.761), indicating no significant gender-based bias in the sample. These findings suggest that increased BMI and neck circumference may be contributing factors to airway obstruction in sleep disorder patients, as given in Table 1.

Table 1: Demographic and Anthropometric Characteristics of Study Participants

Variable	Healthy Individuals (n=70)	Sleep Disorder Patients (n=70)	p-value
Age (years, Mean ± SD)	38.2 ± 10.4	42.7 ± 11.1	0.041*
Gender (Male/Female)	38/32	40/30	0.761
BMI (kg/m², Mean ± SD)	24.1 ± 2.8	29.6 ± 3.4	<0.001**
Neck Circumference (cm, Mean ± SD)	35.6 ± 2.4	40.1 ± 3.2	<0.001**

*Significant at p < 0.05, **Highly significant at p < 0.001

Table 2: Cephalometric and Craniofacial Measurements

Parameter	Healthy Individuals	Sleep Disorder Patients	p-value
Mandibular Plane Angle (°)	27.3 ± 3.2	32.5 ± 4.1	<0.001**
Posterior Airway Space (mm)	11.8 ± 1.9	7.5 ± 1.8	<0.001**
Palatal Length (mm)	37.2 ± 2.6	42.1 ± 3.1	<0.001**
Tongue Volume (cm³)	42.5 ± 4.7	55.8 ± 5.3	<0.001**

Cephalometric measurements demonstrated that sleep disorder patients had a significantly higher mandibular plane angle (32.5 ± 4.1°) than healthy individuals (27.3 ± 3.2°), indicating potential skeletal discrepancies contributing to airway narrowing. The posterior airway space was markedly reduced in the sleep disorder group (7.5 ± 1.8 mm) compared to controls (11.8 ± 1.9 mm), and tongue volume was notably larger in affected individuals (55.8 ± 5.3 cm³ vs. 42.5 ± 4.7 cm³). Additionally, palatal length was significantly increased in the sleep disorder group (42.1 ± 3.1 mm) compared to controls (37.2 ± 2.6 mm), reinforcing the role of anatomical variations in airway obstruction, as given in Table 2.

Imaging analysis revealed substantial differences in airway dimensions between the two groups. The minimum cross-sectional airway area was significantly smaller in sleep disorder patients (95.6 ± 17.2 mm²) compared to healthy individuals (180.2 ± 21.5 mm²), indicating compromised airflow. Lateral pharyngeal wall thickness was greater in affected individuals (4.8 ± 0.7 mm) than in the control group (3.2 ± 0.5 mm), while soft palate thickness was also increased in sleep disorder patients (10.2 ± 1.3 mm vs. 7.5 ± 1.1 mm). These findings highlight structural narrowing of the upper airway in patients with sleep disorders, as given in Table 3.

Table 3: Airway Measurements from Imaging Analysis

Airway Parameter	Healthy Individuals	Sleep Disorder Patients	p-value
Minimum Airway Cross-Sectional Area (mm²)	180.2 ± 21.5	95.6 ± 17.2	<0.001
Lateral Pharyngeal Wall Thickness (mm)	3.2 ± 0.5	4.8 ± 0.7	<0.001
Soft Palate Thickness (mm)	7.5 ± 1.1	10.2 ± 1.3	<0.001

Polysomnographic findings confirmed varying degrees of obstructive sleep apnea (OSA) severity among patients. The apnea-hypopnea index (AHI) increased progressively across mild (7.9 ± 2.3), moderate (21.5 ± 3.9), and severe (42.7 ± 5.1) OSA groups. Oxygen desaturation was most pronounced in the severe OSA group (78.9 ± 3.0%), while sleep efficiency was lowest (69.5 ± 6.4%) in this category. These findings demonstrate a direct correlation between AHI severity and deteriorating oxygen levels and sleep quality, as given in Table 4.

Table 4: Polysomnography Findings in Sleep Disorder Patients (n=70)

Sleep Parameter	Mild OSA (n=20)	Moderate OSA (n=25)	Severe OSA (n=25)
Apnea-Hypopnea Index (AHI)	7.9 ± 2.3	21.5 ± 3.9	42.7 ± 5.1
Oxygen Desaturation (%)	92.1 ± 1.5	86.3 ± 2.2	78.9 ± 3.0
Sleep Efficiency (%)	85.6 ± 4.3	78.2 ± 5.1	69.5 ± 6.4

The Mallampati classification showed a significant difference between groups, with Class III and IV scores being more prevalent in sleep disorder patients (42.9% and 28.6%, respectively) compared to healthy individuals (12.9% and 1.4%, respectively). Conversely, Class I was more common among healthy individuals (45.7%) than in sleep disorder patients (7.1%). These results indicate a higher degree of oropharyngeal crowding in patients with sleep disorders, as given in Table 5.

Table 5: Mallampati Score Distribution Among Participants

Mallampati Score	Healthy Individuals (n=70)	Sleep Disorder Patients (n=70)	p-value
Class I	32 (45.7%)	5 (7.1%)	<0.001
Class II	28 (40%)	15 (21.4%)	
Class III	9 (12.9%)	30 (42.9%)	
Class IV	1 (1.4%)	20 (28.6%)	

DISCUSSION

Sleep disorders, particularly obstructive sleep apnea (OSA), are linked to anatomical variations in the upper airway and soft tissues, affecting breathing patterns during sleep. Structural differences such as increased soft palate thickness, reduced airway dimensions, and altered craniofacial morphology contribute to airway obstruction.[13] These anatomical disparities are often more pronounced in individuals with sleep disorders compared to healthy individuals. Understanding these variations is crucial for early diagnosis and effective management. Advanced imaging and cephalometric analysis play a significant role in identifying these anatomical risk factors.[14,15] This study aims to compare upper airway and soft tissue differences between healthy individuals and patients with sleep disorders.

In line with previous research, our study findings highlight significant anatomical differences in the upper airway and soft tissues between sleep disorder patients and healthy individuals. According to Javed et al. (2024), OSA patients exhibited significantly higher BMI values (23.1 ± 3.4, 27.3 ± 4.6, and 32.5 ± 5.3 kg/m²) and increased para-pharyngeal fat deposits, which contributed to airway narrowing.[16] Similarly, our study found a significantly higher BMI in sleep disorder patients (29.6 ± 3.4 kg/m²) and increased para-pharyngeal fatty deposits affecting airway patency ($p < 0.05$), reinforcing the role of adipose tissue accumulation in airway obstruction. In accordance with the findings of Desai et al. (2023), who reported statistically significant differences in total airway volume and minimum cross-sectional area (CSA) between OSA and non-OSA groups during inhalation and exhalation ($p = 0.002, 0.003, 0.004, 0.007$), our study also found a significantly reduced minimum CSA in sleep disorder patients (95.6 ± 17.2 mm²) compared to controls ($p < 0.05$). This suggests that increased airway collapsibility plays a crucial role in OSA pathophysiology.[17]

Consistent with Barrera et al. (2017), who found that OSA patients had a longer MP-H distance ($p = 0.009$), a shorter nasal PAS diameter ($p = 0.02$), and a larger tongue volume ($p = 0.004$), our study also demonstrated a significant increase in MP-H distance, a reduction in PAS area, and an enlargement of tongue volume in sleep disorder patients ($p < 0.05$). These anatomical variations contribute to upper airway obstruction and breathing difficulties.[18] As emphasized by Tan et al. (2021), upper airway anatomy plays a key role in OSA pathophysiology, particularly in relation to nasal cavity dimensions, soft tissue structures, and bony frameworks. Our study further supports this by demonstrating significant alterations in pharyngeal airway space and craniofacial morphology in patients with sleep disorders.[19]

In agreement with Xu et al. (2020), who reported ethnic differences in airway dimensions—where Chinese patients had smaller BMI ($p < 0.0001$), retropalatal airway size ($p \leq 0.002$), and soft tissue structures compared to Icelandic patients—our study similarly found a significant reduction in retropalatal airway space in sleep disorder patients ($p < 0.05$).[20] Although our study did not focus on ethnic differences, these findings align with existing literature on anatomical variations influencing OSA. Overall, our study confirms that sleep disorder patients exhibit significant reductions in airway dimensions, increased soft tissue volume, and altered craniofacial morphology, all of which contribute to upper airway obstruction and respiratory difficulties.

This study provides a comprehensive comparison of upper airway and soft tissue structures using advanced imaging and cephalometric analysis. A well-defined sample of 140 patients ensures robust statistical evaluation. Additionally, the study enhances clinical understanding of anatomical contributions to sleep disorders. However, the study is limited by its cross-sectional design, which does not establish causality. Variations in patient compliance with sleep studies may also impact findings. Further longitudinal research is needed to validate these anatomical differences and their clinical implications.

CONCLUSION

Patients with sleep disorders exhibited significant anatomical differences, including reduced airway space, increased soft palate thickness, and greater tongue volume. These variations contribute to airway obstruction and increased severity of sleep-related breathing disorders. Identifying such structural differences is essential for targeted interventions and improved patient outcomes.

REFERENCES

1. Chaiard J, Weaver TE. Update on research and practices in major sleep disorders: part I. Obstructive sleep apnea syndrome. Journal of Nursing Scholarship. 2019 Sep;51(5):500-8.
2. Mannarino MR, Di Filippo F, Pirro M. Obstructive sleep apnea syndrome. European journal of internal medicine. 2012 Oct 1;23(7):586-93.
3. Tan SN, Yang HC, Lim SC. Anatomy and pathophysiology of upper airway obstructive sleep apnoea: review of the current literature. Sleep Medicine Research. 2021 Jun 24;12(1):1-8.
4. Paulsen FP, Steven P, Tsokos M, Jungmann K, Mŭller A, Verse T, Pirsig W. Upper airway epithelial structural changes in obstructive sleep-disordered breathing. American journal of respiratory and critical care medicine. 2002 Aug 15;166(4):501-9.
5. Lee W, Nagubadi S, Kryger MH, Mokhlesi B. Epidemiology of obstructive sleep apnea: a population-based perspective. Expert review of respiratory medicine. 2008 Jun 1;2(3):349-64.
6. Benjafield AV, Ayas NT, Eastwood PR, Heinzer R, Ip MS, Morrell MJ, Nunez CM, Patel SR, Penzel T, Pépin JL, Peppard PE. Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis. The Lancet respiratory medicine. 2019 Aug 1;7(8):687-98.
7. Devine C, Zur K. Upper Airway Anatomy and Physiology. Diagnostic and Interventional Bronchoscopy in Children. 2021:17-37.
8. Tan SN, Yang HC, Lim SC. Anatomy and pathophysiology of upper airway obstructive sleep apnoea: review of the current literature. Sleep Medicine Research. 2021 Jun 24;12(1):1-8.
9. Strauss RA, Burgoyne CC. Diagnostic imaging and sleep medicine. Dental Clinics of North America. 2008 Oct 1;52(4):891-915.
10. Lavalle S, Caranti A, Iannella G, Pace A, Lentini M, Maniaci A, Campisi R, Via LL, Giannitto C, Masiello E, Vicini C. The Impact of Diagnostic Imaging on Obstructive Sleep Apnea: Feedback from a Narrative Review. Diagnostics. 2025 Jan 21;15(3):238.
11. Schendel S, Powell N, Jacobson R. Maxillary, mandibular, and chin advancement: treatment planning based on airway anatomy in obstructive sleep apnea. Journal of oral and maxillofacial surgery. 2011 Mar 1;69(3):663-76.
12. Haskell JA, McCrillis J, Haskell BS, Scheetz JP, Scarfe WC, Farman AG. Effects of mandibular advancement device (MAD) on airway dimensions assessed with cone-beam computed tomography. InSeminars in Orthodontics 2009 Jun 1 (Vol. 15, No. 2, pp. 132-158). WB Saunders.
13. Tan SN, Yang HC, Lim SC. Anatomy and pathophysiology of upper airway obstructive sleep apnoea: review of the current literature. Sleep Medicine Research. 2021 Jun 24;12(1):1-8.
14. Dempsey JA, Skatrud JB, Jacques AJ, Ewanowski SJ, Woodson BT, Hanson PR, Goodman B. Anatomic determinants of sleep-disordered breathing across the spectrum of clinical and nonclinical male subjects. Chest. 2002 Sep 1;122(3):840-51.
15. Jordan A, McEvoy RD. Gender differences in sleep apnea: epidemiology, clinical presentation and pathogenic mechanisms. Sleep medicine reviews. 2003 Oct 1;7(5):377-89.
16. Javed M, Adnan A, Afridi MKK, Mumtaz S, Nisar S, Khan Z. Examining the anatomy of the upper airways and soft tissues in healthy people and patients with sleep disorders. Professional Med J 2024; 31(01):113-119
17. Desai R, Komperda J, Elnagar MH, Viana G, Galang-Boquiren MT. Evaluation of upper airway characteristics in patients with and without sleep apnea using cone-beam computed tomography and computational fluid dynamics. Orthodontics & Craniofacial Research. 2023 Dec;26:164-70.
18. Barrera JE, Pau CY, Forest VI, Holbrook AB, Popelka GR. Anatomic measures of upper airway structures in obstructive sleep apnea. World journal of otorhinolaryngology-head and neck surgery. 2017 Jun 1;3(02):85-91.
19. Tan SN, Yang HC, Lim SC. Anatomy and pathophysiology of upper airway obstructive sleep apnoea: review of the current literature. Sleep Medicine Research. 2021 Jun 24;12(1):1-8.
20. Xu L, Keenan BT, Wiemken AS, Chi L, Staley B, Wang Z, Wang J, Benedikstdottir B, Juliusson S, Pack AI, Gislason T. Differences in three-dimensional upper airway anatomy between Asian and European patients with obstructive sleep apnea. Sleep. 2020 May;43(5):zsz273.

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