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Original Article

Pharyngeal airway analysis in obese and non-obese patients with obstructive sleep apnea syndrome

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ABSTRACT

Background: Sleep disorders are a group of disorders characterized by abnormalities of respiration during sleep. OSA (Obstructive Sleep Apnea) is characterized by the repetitive episodes of complete or partial collapse of the upper airway during sleep, causing a cessation or a significant reduction of airflow.

Method: The study population consisted of 30 control patients (AHI ≤ 5) events per hour, 74 patients with OSAS, including 34 Obese (BMI ≥ 27) and 40 non-obese (BMI ≤ 27). Polysomnography and measurements of 21 cephalometric variables were carried out for all patients with OSAS.

Results: Obese patient with OSAS showed significant difference in following cephalometric parameters: (1) PAS (2) MPT (3) MPH (4) PNS-P (5) SAS. In addition, obese patient had longer tongue (TGL), more anteriorly displaced hyoid bones (H-VL) and more anterior displacement of mandible (G-VL) when compared with control groups. The findings of non-obese patients when compared to controls showed all the findings of obese patients and in addition to that narrow bony oropharynx were significant. Step wise regression analysis showed the significant predictors for all patients were MPH, PNS-P, bony nasopharynx (PNSBa), MPT, and palatal length (ANS-PNS) for AHI. The significant predictors for obese OSA (obstructive sleep apnea) group were MAS while for non-obese OSA group ANS-PNS was significant predictor for AHI (apnea-hypopnea index).

Conclusion: Craniofacial landmarks such as increase in hyoid distance, longer tongue and soft palate with increased thickness and narrowing of superior pharyngeal, oropharyngeal and hypopharyngeal airway space may be important risk factors for development of OSAS.

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Introduction

Obstructive sleep apnea (OSA) is a potentially life threatening disorder linked to deteriorate systemic health and known as a risk and possible causative factor in developing of systemic hypertension, depression, stroke, angina and cardiac dysarrhythmias.^{1–6}

Cephalogram is a standardized lateral radiograph of the head and neck used to examine craniofacial structures, soft tissues and upper airway. It is the most important basic diagnostic tool to study airway dimensions with considerable accuracy and predictability. Recent studies have illustrated high correlation in pharyngeal airway space measured by cephalograms and measurements using a three dimensional computed tomography scan.⁷ Craniofacial defects including mandibular deficiency, soft tissue enlargement and inferior displacement of the hyoid bone have been proposed to be predisposing factors to upper airway obstruction during sleep in patients with OSA.^{8–10}

Increased BMI has been implicated to be one of the most significant predisposing factors for the upper airway sleep disorders.^{11,12} Based on the possible effect/influence of BMI on upper respiratory sleep disorders, the patients with OSA can be divided into non-obese with craniofacial abnormalities, obese with craniofacial abnormalities and obese with normal craniofacial anatomy when bony structures are well placed but with truncular obesity and enlarged neck circumference.

Greater incidence of abnormalities in craniofacial anatomy has been demonstrated in Asian patients with OSA.^{13,14} There is paucity of literature available for Asian population, with only one study reported for urban Indian subjects.¹⁵ Therefore the objective of the present study was to evaluate the cephalometric features in normal subjects and OSA patients in mixed Indian population and to ascertain the relationship between cephalometric variables and apnea-hypopnea index (AHI) in the study population.

Material and methods

Subjects: The study population ($n = 104$) consisted of one hundred and four OSAS (obstructive sleep apnea syndrome) patients of mixed Indian origin consequently referred to Army Dental Centre (R & R) New Delhi and department of dental surgery, AFMC Pune between Apr 2005 and Aug 2013 for craniofacial examination with lateral cephalograms and feasibility of oral appliance therapy. All the study subjects who had AHI ≥ 10 events per hr recorded during overnight Type 1 polysomnography (PSG). Based on the body mass index (BMI) the OSA patients were subdivided into two groups i.e. obese OSA (BMI ≥ 27 kg-m², $n = 34$) and non-obese (BMI < 27 , $n = 40$). The criteria of selection of control group (BMI < 27 , $n = 30$) included good health, absence of any sleep disordered breathing (AHI < 5 events/h), oxygen saturation $>90\%$ and absence of any subjective symptoms related to OSA.

Cephalometric analysis: The study subjects and control had undergone standard lateral cephalometry. Cephalograms were recorded in natural head position at end expiration phase, without swallowing and in centric occlusion. All cephalograms were traced manually by single operator

adopting standardized technique, and were not made aware of the clinical status. 21 variables representing both craniofacial skeletal and soft tissue morphology were measured as angular (degrees) or linear (millimeters) by a single observer. Every measurement was made three times by the same observer in a single-blind manner and the mean value of the two nearest measurements was used for the statistical analyses to ensure reliability.

The cephalometric landmarks and reference lines are defined in Table 1 and illustrated anatomically in Fig. 1. Definition of cephalometric landmarks and reference lines are defined in Table 2.

Statistical analysis: The categorical variables were described using percentage and quantitative variables by mean $\pm$ standard deviation (SD). To assess whether there is significant difference in the three groups namely obese OSAS, non-obese OSAS and control group one way analysis of variance (ANOVA) was used after testing for homogeneity of variances. Wherever homogeneity assumption failed non parametric equivalent Kruskal Wallis test was applied. Pairwise differences were detected by LSD (Least Square

Table 1 – Landmarks included in the study with reference lines.

1.	S	Sella, midpoint of the fossa hypophysealis
2.	N	Nasion, anterior point at the frontonasal suture
3.	ANS	Anterior nasal spine, most anterior point of the nasal spine
4.	A	Deepest anterior point in the concavity of the anterior maxilla
5.	B	Deepest anterior point in the concavity of the anterior mandible
6.	Go	Gonion, a mid-plane point at the gonial angle located by bisecting the posterior and inferior borders of the mandible
7.	Me	Menton, most inferior point of the chin bone
8.	Ba	Basion, most posteroinferior point on the clivus
9.	AA	Anterior atlas
10.	G	Most posterior point on the symphysis of the mandible
11.	P	Lowest point of the soft palate
12.	TT	Most anterior point of the tip of the tongue
13.	H	Most anterosuperior point of the hyoid bone
14.	V	Most anteroinferior point of the epiglottic fold
15.	NS	Nasion-sella line, a line through N and S
16.	MP	Mandibular plane, a plane constructed from Me through Go
17.	VL	A line across C3 and C4
18.	TGL	The distance between the landmarks V and TT
19.	TGH	The linear distance along the perpendicular bisector of the V-TT line to the tongue dorsum

Fig. 1 – Cephalometric anatomic and constructed landmarks.

Differences) method. ANOVA was also carried out for gender differences in the three groups separately. Reliability for all parameters is given in terms of 95% confidence interval (CI) for all groups. Correlation between various cephalometric variables with AHI and BMI was examined using Pearson's product correlation coefficient. Multiple Regression analysis was carried out to predict AHI independently. This analysis was performed for all patients with OSAS in each predefined subgroup of obese and non-obese patients separately. Before running the regression model the multicollinearity in the independent variables were tested using variance inflation factor (VIF). VIF value of 5 indicated further investigation and above 10 indicated serious multicollinearity problem requiring correction. The results of regression were validated by determining R^2 value. A p value of <0.05 was considered significant.

Results

In this cross sectional study a total of 104 subjects including 34 obese, 40 non-obese OSAS patients along with 30 controls were studied in order to seek differences in the cephalometric variables. Age, BMI and PSG data of all the OSAS patients and control group are presented in Table 3. There was no significant difference in BMI in the non-obese OSA and the control group. It was also observed that there was no significant difference in the age and gender distribution in three groups ($p > 0.05$) making the groups comparable. When compared the cephalometric variables in all groups, obese patients showed more AHI and ODI as against non-obese patients. When compared with control group, obese patients with OSAS

Table 2 – Definition of cephalometric landmarks and reference lines.

1. SNA	Angle between S-N and N-A
2. SNB	Angle between S-N and N-B
3. ANB	Angle between N-A and N-B
4. NSBa (cranial base flexure),	Angle between S-N and a line from S to Ba
5. BMeH	Angle between B-Me and Me-H
6. GoMeN	Angle between Go-Me and Me-N
7. G-VL	Linear distance along a perpendicular plane from G to VL
8. S-N	Distance between S and N
9. N-Ba	Distance between N and Ba
10. ANS-PNS	Distance between ANS and PNS
11. PNS-AA (bony oropharynx)	Distance between PNS and AA
12. PNS-Ba (bony nasopharynx)	Distance between PNS and Ba
13. MP-H	Linear distance along a perpendicular plane from H to MP
14. H-VL	Linear distance along a perpendicular plane from H to VL
15. PNS-P	Distance between PNS and P
16. MPT	Greatest thickness of the soft palate
17. TGL	Distance between V and TT
18. TGH	Linear distance along the perpendicular bisector of the V-TT line to the tongue dorsum
19. SAS(Superior airway space)	Narrowest part of the airway between PNS and P
20. PAS (Posterior airway space)	Narrowest part of the airway between P and Go
21. MAS (Minimum airway space)	Airway width along the Go-B plane

showed significant difference in following cephalometric parameters: (1) decrease in posterior airway space (PAS); (2) increased soft palate thickness (MPT); (3) inferior position of hyoid (MPH); (4) increase in length of soft palate (PNS-P); (5) decrease in superior pharyngeal airway space (SAS). In addition, obese patient had longer tongue (TGL), more anteriorly displaced hyoid bone (H-VL) and more anterior displacement of mandible (G-VL) when compared with control group. Similarly, a comparison with non-obese patients showed more anteriorly displaced hyoid, longer tongue and soft palate. However, non-obese patients had significantly decreased bony pharynx, palatal length, posteriorly placed mandible, narrow superior airway space (SAS). The one way ANOVA revealed that there is significant difference in the three groups with respect to majority of the cephalometric variables. Further multiple comparison by LSD test showed significant ($p = 0.000$) differences in obese and non-obese group for SNA, SNB, ANB, GVL, Ba-SN, Ba-N, SN, ANS-PNS, PNS-Ba, PNS-aa, GoMeN, MPT, PNS-P, TGL, TGH, BMeH, MPH, HVL, MAS, SAS whereas significant difference ($p = 0.000$) was observed in obese and control group for SNA, GVL, Ba-N, SN, ANS-PNS, PNS-Ba, PNS-AA, GoMeN, MPT, PNS-P, TGL, TGH, BMeH, MPH, HVL, PAS, MAS, SAS. Following parameters were significant ($p = 0.000$) when compared in non-obese and control group in MPT, PNS-P, TGH, BMeH, MPH, PAS, MAS, and SAS. Descriptive statistics along with multiple comparisons of the

Table 3 – Patient characteristics and cephalometric measurements in obese, non-obese with OSAS with control patient's[#].

Characteristics	Obese OSAS (n = 34) (95% CI)	Non-obese OSAS (n = 40) (95% CI)	Control (n = 30) (95% CI)	
Age (yr)	53.2 ± 4.8 (51.51, 54.81)	53.6 ± 4.0 (52.36, 54.84)	52.7 ± 2.6 (51.77, 53.63)	
BMI	33.7 ± 2.7 (32.79, 34.61)	23.45 ± 1.6 (22.95, 23.95)	22.8 ± 2.4 (21.94, 23.66)	
AHI (Events/Hr)	54.47 ± 2.7 (53.56, 55.38)	42.12 ± 2.3 (41.41, 42.83)	2.94 ± 1.4 (2.44, 3.44)	
ODI (Events/Hr)	58.8 ± 25.7 (50.16, 67.44)	34.26 ± 8.6 (31.59, 36.93)	4.9 ± 2.2 (3.86, 5.94)	
Parameters	Obese OSA (n = 34) 95% CI	Non-obese OSA (n = 40) 95% CI	Control (n = 30) 95% CI	All groups (n = 104)
Skeletal structure				
SNA ^o	85.62 ± 0.779 ^{††} (85.36, 85.88)	84.28 ± 2.418 [‡] (83.53, 85.03)	84.73 ± 1.388 [‡] (84.23, 85.23)	84.85 ± 1.810
SNB ^o	79.12 ± 0.913 [‡] (78.81, 79.43)	78.28 ± 2.331 [‡] (77.56, 79.00)	78.90 ± 1.918 (78.21, 79.59)	78.73 ± 1.871
ANB ^o	6.53 ± 0.563 [‡] (6.36, 6.70)	6.15 ± 0.834 [‡] (5.84, 6.36)	6.20 ± 0.847 (5.90, 6.50)	6.29 ± 0.772
G-VL,mm	77.79 ± 9.095 ^{††} (74.76, 80.82)	71.18 ± 2.890 [‡] (70.28, 72.08)	70.07 ± 4.927 [†] (68.31, 71.83)	73.02 ± 6.920
BaSN	130.38 ± 0.853 [‡] (130.09, 130.67)	128.48 ± 2.80 [‡] (127.61, 129.35)	129.63 ± 5.216 (127.76, 131.50)	129.43 ± 3.39
BaN	115.0 ± 1.808 ^{††} (114.45,115.67)	110.20 ± 5.61 [‡] (108.46,111.94)	109.93 ± 4.21 [†] (108.42,114.44)	111.71 ± 4.84
SN ^o	73.29 ± 2.316 ^{††} (72.51, 74.07)	71.13 ± 1.66 [‡] (70.58, 71.62)	71.53 ± 1.456 [‡] (71.01, 72.05)	71.95 ± 2.069
ANS-PNS	54.00 ± 2.523 ^{††} (53.16, 54.84)	50.35 ± 3.00 [‡] (49.42, 51.28)	49.67 ± 2.746 [†] (48.69, 50.65)	51.35 ± 3.332
PNS-Ba	47.62 ± 2.174 ^{††} (46.89, 48.35)	45.15 ± 2.413 [‡] (44.40, 45.90)	44.20 ± 2.524 [†] (43.30, 45.10)	45.68 ± 2.739
PNS-aa	37.53 ± 0.992 [‡] (37.20, 37.86)	35.43 ± 5.349 [‡] (33.74, 37.06)	36.70 ± 4.843 (34.97, 38.43)	36.48 ± 4.308
GoMeN ^o	69.21 ± 1.533 ^{††} (68.69, 69.73)	66.38 ± 2.789 [‡] (65.52, 67.24)	65.20 ± 3.585 [†] (64.20, 68.75)	66.96 ± 3.165
Soft tissues, mm				
PNS-P	51.09 ± 1.240 ^{††} (50.58, 51.42)	42.95 ± 3.789 ^{†¶} (41.78, 44.12)	34.73 ± 3.290 ^{†¶} (33.55, 35.91)	43.24 ± 7.101
G	13.29 ± 1.129 ^{††} (12.82, 13.58)	10.48 ± 0.987 ^{†¶} (10.17, 10.79)	11.60 ± 3.440 ^{†¶} (10.37, 12.83)	11.72 ± 2.367
TGL	93.76 ± 3.358 ^{††} (92.65, 94.87)	83.75 ± 4.390 [‡] (82.39, 85.11)	82.70 ± 4.886 [‡] (80.95, 84.45)	86.72 ± 6.492
TGH	38.82 ± 4.496 [†] (37.31, 40.33)	37.98 ± 2.166 [¶] (37.31, 38.65)	34.27 ± 5.953 ^{†¶} (32.14, 36.40)	37.18 ± 4.673
Hyoid bone positions				
BMeH	113.79 ± 4.333 ^{††} (112.33, 115.25)	109 ± 4.654 ^{†¶} (107.56, 110.44)	91.37 ± 7.950 ^{†¶} (88.53, 94.21)	105.61 ± 10.9
MP-H	26.38 ± 2.015 ^{††} (25.63, 26.97)	22.93 ± 2.390 ^{†¶} (22.19, 23.67)	14.90 ± 2.796 ^{†¶} (13.90, 15.90)	21.74 ± 5.2
H-VL	47.71 ± 2.638 ^{††} (46.84, 48.58)	41.25 ± 4.331 [‡] (39.91, 42.59)	40.17 ± 4.001 [†] (38.74, s41.60)	43.05 ± 4.92
Pharyngeal dimension, mm				
PAS	8.38 ± 0.853 [‡] (8.09, 8.67)	7.85 ± 1.45 [¶] (7.40, 8.30)	11.30 ± 2.806 ^{†¶} (10.30, 12.30)	9.02 ± 2.34
MAS	12.00 ± 1.044 ^{††} (11.65, 12.35)	10.05 ± 1.797 ^{†¶} (9.60, 10.50)	15.13 ± 2.991 ^{†¶} (14.06, 16.20)	12.15 ± 2.9
SAS	7.56 ± 1.078 ^{††} (7.20, 7.92)	8.13 ± 0.966 ^{†¶} (7.83, 8.43)	9.03 ± 1.217 ^{†¶} (8.59, 9.47)	8.20 ± 1.128

[†]p < 0.05 Obese OSA – Non-obese OSA.

^{†¶}p < 0.05 Non-obese OSA – Controls OSA.

[‡]p < 0.05 Obese OSA – Controls OSA.

[†]p < 0.05 Obese OSA – Non-obese OSA.

^{††}p < 0.05 Non-obese OSA – Controls OSA.

[‡]p < 0.05 Obese OSA – Controls OSA.

various variables between the groups are presented in Table 3. Gender wise differences in the three groups are similarly given in Table 4. In males the significant difference were present in SN, MPT, TGH, PAS, MAS, AHI, ODI whereas in females it was observed that GVL, BAN, SN, MPT, PNS-P, MPT, GH, TGL, TGH, BMeH, AHI, ODI were statistically significant.

The correlation between various cephalometric variables with AHI and BMI in obese and non-obese patients was determined by correlation coefficient. Within obese group positive moderate to good significant correlation of SN ($r = 0.613$, $p = 0.00$) and ANS-PNS ($r = 0.68$, $p = 0.00$) was observed with AHI. Similarly BMI showed positive moderate correlation with facial A-P distance at the maxilla levels, ANS-PNS (0.43 , $p = 0.0012$) and PNS-Ba ($r = 0.38$, $p = 0.028$). Within non-obese patients AHI correlated negatively with Ba-N ($r = -0.343$, $p = 0.03$) whereas in the same group BMI showed moderate positive correlation with G-VL ($r = 0.375$, $p = 0.016$), Ba-SN ($r = 0.449$, $p = 0.004$), SN ($r = 0.640$, $p = 0.00$), ANS-PNS ($r = 0.82$, $p = 0.00$), PNA-Ba ($r = 0.65$, $p = 0.00$). Significant moderate correlation was observed in AHI and BMI for obese patients ($r = 0.55$, $p = 0.001$).

Regression analysis was carried out to predict AHI based on cephalometric variables for all patients. The model was also rerun for subgroup of obese and non-obese patients independently. The regression model was significant for all patients as well as for obese and non-obese OSA patients. For all patients including obese and non-obese OSA together, multicollinearity was seen for SNA, SNB, and BMI with VIF values more than 10. After correcting for multicollinearity, the significant predictors for all patients were MPH, PNS-P, PNS-Ba, MPT, and ANS-PNS. The model gave coefficient of determination (R^2) of almost 92% implying the good model fit with 93% of variability in AHI being explained by the various predictors as shown in Table 5. For all patients, the regression model for AHI was highly significant for following determinants: ANS-PNS ($R = 0.42$, $R^2 = 0.18$, $\beta = 0.234$, $p = 0.002$), PNS-P ($R = 0.43$, $R^2 = 0.19$, $\beta = 0.26$, $p = 0.001$), G ($R = 0.29$, $R^2 = 0.09$, $\beta = 0.15$, $p = 0.029$), MPH ($R = 0.41$, $R^2 = 0.17$, $\beta = -0.18$, $p = 0.002$), PNS-Ba ($R = 0.404$, $R^2 = 0.16$, $\beta = 0.23$, $p = 0.003$). The significant predictors for obese OSA group were MAS ($R = -0.55$, $R^2 = 0.30$, $\beta = -0.294$, $p = 0.04$) while for non-obese OSA group ANS-PNS ($R = 0.64$, $R^2 = 0.41$, $\beta = 0.60$, $p = 0.003$) was significant predictor.

Table 4 – Gender wise distribution and differences in cephalometric measurements.

Parameters	p-Value	Group wise comparison		
		Obese	Non-obese	Control
Males				
SN	0.01	††	‡	†
MPT	0.038	‡	‡	
TGH	0.048	‡	‡	
PAS	0.000	†	¶	†¶
MAS	0.002	‡	‡¶	¶
AHI	0.000	†	¶	†¶
ODI	0.000	††	‡¶	s
Females				
GVL	0.002	‡	‡	
BaN	0.005	‡	‡	
SN	0.031	‡	‡	
G	0.003	††	‡	†
PNS-P	0.011	†		†
MPT	0.005	††	‡	†
TGH	0.021	‡	‡	
BMeH	0.008	‡	‡	
AHI	0.000	†	¶	†¶
ODI	0.000	††	‡¶	¶†
†p < 0.05 Obese OSA – Non-obese OSA.				
¶p < 0.05 Non-obese OSA – Controls OSA.				
‡p < 0.05 Obese OSA – Controls OSA.				

Discussion

Sleep related breathing disorders are a group of disorders characterized by abnormalities of respiration during sleep. OSA is characterized by the repetitive episodes of complete or partial collapse of the upper airway during sleep, causing a cessation (obstructive apnea) or a significant reduction (obstructive hypopnea) of airflow.¹⁶ Narrowing of airway segments in various parts of upper airway and knowledge of its location is central to an understanding of the pathogenesis of OSA.^{9,17} Various studies including one study on urban Indian subjects have shown significant cephalometric findings in OSA patients.¹⁵ These include retrognathic mandible, decreased posterior airway space/retroglossal space, elongation of soft palate and increased hyoid distance and thickness of soft palate.^{18–23} A comparison with control group showed that obese and non-obese patients with OSAS were commonly characterized by the following cephalometric parameters: decrease in posterior airway space (PAS), increased in soft palate thickness (MPT), inferior position of hyoid (MPH), increase in length of soft palate (PNS-P), decrease in superior pharyngeal airway space (SAS). In addition, obese patient had longer tongue (TGL), more anteriorly displaced hyoid bones (H-VL) and more anterior displacement of mandible (G-VL) when compared with control groups. In addition non-obese patients showed significant decrease in bony nasopharynx and oropharynx when compared to obese group patients. Step wise regression analysis showed that significant predictors for all patients were MPH, PNS-P, MPT, and ANS-PNS for AHI. The significant predictors for obese OSA group were MAS while for non-obese OSA group; ANS-PNS was significant predictor for AHI. Craniofacial anatomic risk factors are said to play a role

Table 5 – Multiple regression results for overall, group I and group II.

Parameters	Overall			
	Beta (Standardized coefficients)	p- Value	95% Confidence interval for beta	
			Lower bound	Upper bound
With AHI (Overall)				
MPH	0.178	0.002	0.16	0.69
PNS-P	0.257	0.001	0.14	0.54
G	0.152	0.029	0.059	1.08
ANS-PNS	0.234	0.002	0.18	0.75
PNS-Ba	0.23	0.003	0.20	0.89
With AHI (Obese OSA)				
PNS-Ba	0.632	0.000	0.46	1.11
MAS	−0.294	0.04	−0.039	−0.15
With AHI (Non-obese OSA)				
ANS-PNS	0.60	0.003	0.18	0.75

in OSAS, together with the mechanism of upper airway compliance and muscle function. Several studies have recommended the use of cephalometric radiographs to characterize the craniofacial hard and soft tissue structures of the patients with and without OSAS.^{24–28}

Sakakibara et al observed that the etiology of OSA in non-obese Japanese patients appears to be somewhat different which includes bony structure discrepancies.¹² Non-obese OSA patients tend to present the following anatomical craniofacial characteristics such as caudal hyoid, increased soft palate dimensions, and consequent anteroposterior reductions of the airways at the soft palate level, reduction of anteroposterior region of nasopharynx, and oral pharynx. Our study on urban Indian mixed population in the non-obese group is comparable to the above cited study. OSA patients can present with these findings but in addition they have increased volume of tongue and anterior hyoid bone. Lower and anterior position of hyoid bone in obese patients seems to be related to increased fat deposition on the tongue, which increases its volume.^{29,30} Our findings with respect to obese patients group are in agreement and comparable with above cited studies.

It has been suggested that the discrepancy in cephalometric measurements may also depend on sex, age and race.^{1,13,14,31,32} OSA in Asian men has been found more frequently in non-obese patients, when compared with white male patients with OSAS.³³ In obese patients increased tongue length, anteriorly and inferiorly displace hyoid, anteriorly positioned mandible have been found to be characteristically significant. The decreased tonicity of tongue musculature influenced by gravity in supine position may result in soft palate getting compressed due to falling back of tongue ultimately reducing the adjacent airway space. The hyoid bone is unique as it is not attached to any other bone and geniohyoid. The increase in tongue volume may lower the hyoid as a compensatory phenomenon. This phenomenon has been reflected in previous studies.^{34,35} Our study also showed that the hyoid bone is inferiorly and anteriorly placed in obese patients. Positive correlation between tongue length (G-VL) and AHI has been observed in our study. This means increase in tongue length would increase the AHI.

Significant independent predictors for all patients in our study were MPH, PNS-P, PNS-Ba, MPT, and ANS-PNS. The retro positioned or retrognathic mandible has been attributed as racial characteristic of Japanese OSAS patients. The retro positioned or posteriorly positioned mandible would result in posterior placement of tongue and narrowing in the retro-glossal area. In our study, non-obese groups showed significant difference in ANB and G-VL values suggesting that retro positioned mandible is characteristic in Indian population as well. Many investigators have reported that facial anteroposterior length as measured vide anterior cranial base (SN), palatal length (ANS-PNS) and G-VL shortens in non-obese OSA patients than obese patients.^{11,26,29,30} We have observed same findings in our study and therefore in complete agreement with above observations.

Xinjun Yu et al studied cephalometric features in obese and non-obese 62 Japanese male patients with OSA.³⁶ Their control groups were simple snorers. They have reported several significant cephalometric features in both groups which includes inferiorly positioned hyoid bone, enlarged soft palate and reduced upper airway width at soft palate. Anteriorly positioned hyoid bone and longer tongue was characteristic in obese patients. Bony oropharynx was found to be small and was characteristic in non-obese. Inferior placement of hyoid was dominant determinant of AHI in non-obese patients. We are in agreement with almost all the findings except that in our study we found palatal length (ANS-PNS) as the dominant determinant of AHI in non-obese OSA patients. Our study has both the genders unlike above cited study and in our case the controls were non snorers. The cephalometric variables considered in our study were same as the above cited study. Therefore, we may conclude that there is no difference in the cephalometric features in Japanese and mixed Indian OSA cases.

In conclusion, cephalometric measurements suggestive of increase in length of tongue and soft palate, increased thickness of soft palate, decreased hypopharyngeal, retroglossal, retropalatal airway space and anteriorly placed hyoid bone are characteristic findings in obese OSA patients. Reduced anteroposterior bony oropharynx, posteriorly positioned mandible and inferiorly displaced hyoid bone are characteristic cephalometric findings in non-obese OSA cases. Increased hyoid distance, tongue length, soft palate length and thickness, and anteroposterior palatal distance may play significant role in the severity of OSAS and can be considered as important inputs for diagnosis and treatment planning.

Conflicts of interest

All authors have none to declare.

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