Sleep and Vigilance (2018) 2:127–133
https://doi.org/10.1007/s41782-018-0045-x

ORIGINAL ARTICLE

Correlation of Various Anthropometric and Craniofacial Variables with Severity of Obstructive sleep Apnea in Indian Population

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Received: 27 June 2018 / Accepted: 27 August 2018 / Published online: 11 September 2018

Abstract

Background Ethnic craniofacial morphology differences significantly affect upper airway caliber and thus apnea–hypopnea index (AHI). As there is very limited data available from India regarding factors influencing severity of obstructive sleep apnea (OSA), we tried to explore whether anthropometric and craniofacial variable predict severity of OSA.

Aims To find out correlation of simple clinical examination of craniofacial morphology and anthropometric measurements with severity of OSA in Indian population.

Method We studied consecutive OSA patients between June 2015 and September 2016. Detailed history, physical examination (including anthropometry, clinical craniofacial assessment) and Level I polysomnography was done. Anthropometric and craniofacial parameters were correlated with AHI, nadir oxygen and percent of total time with oxygen saturation level lower than 90% during sleep ($T<90\%$).

Results Out of 193 patients, 148 (76.6%) were males and 45 (23.3%) were females with ratio of 3.28:1. Mean age, mean body mass index (BMI) and mean AHI of cohort were 50.24 ± 1.65 years, 30.20 ± 0.84 kg/m^2, and 53.83 ± 4.8 events per hour, respectively. With respect to AHI, nadir oxygen and $T<90\%$, statistically significant correlation was found for modified Mallampati class (p value $=0.001, =0.009, =0.002$, respectively), waist circumference (p value $=0.002, <0.001, =0.001$, respectively), neck circumference (p value $<0.001, <0.001, <0.001$, respectively), BMI WHO cut off (p value $<0.001, <0.001, <0.001$, respectively), and BMI Asian Indian cut off (p value $=0.001, <0.001, <0.001$, respectively).

Conclusion Anthropometric and craniofacial variables are easy to perform clinical examinations. Higher modified Mallampati class, WC, NC, BMI, large tonsils and micrognathia are associated with more severe OSA.

Keywords Obstructive sleep apnea · Craniofacial abnormality · Obesity

1 Introduction

Obstructive sleep apnea (OSA) is characterized by recurrent partial or complete occlusion of upper airways during sleep [1]. Although both doctors and general population are now becoming more aware of OSA, still the great pool of patients with OSA remain undiagnosed. It is estimated that at least four percent of males and two percent of females suffer from symptomatic OSA [2]. Patients without proper management have significant increased risk of morbidity and mortality secondary to cardiovascular, cerebrovascular and consequences of excessive daytime sleepiness [3].

Several anatomical and pathophysiological factors contribute to OSA development. Obesity, craniofacial feature, loss of muscle tone and collapsibility of upper airways contribute in varying proportion in each case [4]. In spite of lower BMI in Asians compared to western counterparts, the prevalence of OSA in Asian is almost similar to prevalence in Caucasians [2, 5–7]. Craniofacial abnormalities such as a low hyoid bone position, retrognathia, and micrognathia are common predisposing factors for OSA in Asian population. [4, 8, 9]

Scarce data for craniofacial abnormalities are available from Indian population, thus we performed study based on simple clinical examination of craniofacial morphology and anthropometric measurements to predict severity of OSA in Indian population.

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2 Methodology

This prospective analytical study was done at Department of Pulmonary and Sleep Disorders, All India Institute of Medical Sciences (AIIMS) Bhopal. We studied patients consecutively presented to our clinic between June 2015 and September 2016. The patients presenting with symptoms of sleep-disordered breathing were recruited for study. At the time of first visit, after obtaining written consent, each patient underwent detailed history and physical examination including anthropometric measurement and clinical craniofacial morphology assessment. Training of sleep physicians was organized prior to enrollment of patients, during which the measurement techniques for anthropometrical assessment and craniofacial morphology were standardized.

Anthropometric measurements included were body mass index (BMI), neck circumference (NC), waist circumference (WC), hip circumference (HC) and waist/hip ratio (WHR). Craniofacial parameters assessed were modified Mallampati class, tonsil grade, macroglossia, micrognathia, retrognathia, large uvula, high arched palate, cross bite and nasal valve collapse.

We took two cut offs for defining obesity: BMI ≥ 30 kg/m^2 (according to WHO international classification of adult underweight, overweight and obesity) and > 25 kg/m^2 (for Asian Indian population) [10, 11]. Waist was measured at the level of the umbilicus during normal breathe out with tape snugly fitted and horizontal to floor while subject standing with arms at the sides, feet close together [12]. In males and females, waist circumference ≥ 90 and ≥ 80 cm, respectively, was considered abnormal [13]. Hip circumference was measured around the widest portion of the hips with tape snugly fitted and horizontal to floor while subject standing with arms at the sides, feet close together [14]. Waist/hip ratio ≥ 0.90 cm (males); ≥ 0.85 cm (females) was considered abnormal [14]. Neck circumference was measured at the level of the cricothyroid membrane with tape while patient in standing position. NC of > 16 inches for women and > 17 inches for men was considered abnormal [15]. Neck, hip and waist circumferences were repeated twice, and if the measurement was within 1 cm, the average value was taken, and if the measurement exceeded 1 cm, repeat measurement were done till two reading approach within 1 cm to one another. Modified Mallampati class was assessed while the patients sit upright with the head in the neutral position with the mouth wide open, tongue maximally protruded, but without phonation or attempted elevation of the soft palate. According to structures visualized, modified Mallampati classification was done: (a) Class I: soft palate, fauces, uvula, and pillars all are clearly visible; (b) Class II: soft palate, fauces, and uvula are visible; (c) Class III: soft palate and the only base of uvula are visible; (d) Class IV: only the hard palate is visible [16]. For visualization of tonsil, tongue was held in natural neutral position and gently pressed on the floor of mouth. For tonsillar grading, Friedman grading scale was used [17]. Retrognathia was defined as "Posteriorly positioned lower jaw, which is set back from the plane of the face when viewed from the side but not from the front'' [18]. Micrognathia was defined as "Apparently reduced length and width of the mandible when viewed from the front but not from the side" [18]. High arched palate was defined as ''Palatal height at the level of the first permanent molar more than twice the height of the teeth" [19]. Large uvula was defined subjectively by ''Increased length of the uvula'' [19]. Cross bite was defined as a condition where one or more teeth were abnormally placed either lingually or labially with reference to opposing teeth [20]. Nasal valve collapse was assessed using Cottle's maneuver, during which cheek on the same side to be evaluated for nasal valve, was gently pulled laterally with one to two fingers to widen up nasal valve area during quiet breathing [21]. If breathing improved when the nasal valve area is manually widened, it was considered as an indication of nasal valve collapse. Macroglossia was defined as resting tongue protruding beyond teeth or alveolar ridge and causing persistent, artificial, impressions of teeth on lateral margins of tongue when patient opens mouth [22].

3 Polysomnography (PSG)

Every patient underwent level I PSG (Philips Respironics Alice 6) within 1 month after initial assessment. The following parameters were monitored during PSG: Electroencephalogram (EEG)—frontal, central and occipital, electrooculogram (EOG), submentalis electromyogram (EMG), nasal and oral airflow, anterior tibialis EMG, body position and electrocardiogram. Additionally, thoracic and abdominal movements were recorded by inductance plethysmography (zRIP). Oxygen saturation (SpO_2) was monitored using a pulse oximeter. The tracing was scored using 30 s epochs. Apneas were marked when there is drop in peak signal excursion by $\geq 90\%$ of pre-event baseline with duration of the $\geq 90\%$ drop in sensor signal ≥ 10 s. Hypopneas were scored if peak signal excursions drop by $\geq 30\%$ of pre-event baseline with duration of the $\geq 30\%$ drop in signal excursion was ≥ 10 s with associated $\geq 3\%$ oxygen desaturation from pre-event baseline or event was associated with an arousal [23]. Each sleep study was scored in three steps, i.e., first scoring was done by sleep technician which was cross checked by senior resident followed by sleep consultant. The review of PSG by sleep consultant was considered

as final. Severity of OSA was determined by three parameters, namely apnea–hypopnea index (AHI), nadir oxygen levels (minimum oxygen saturation during sleep) and percent of total time with oxygen saturation level lower than 90% during sleep ($T<90\%$). Only patients with AHI ≥ 5 and in age group >18 years were included in study, the rest was excluded from the study.

The study was approved by institutional ethical committee of AIIMS Bhopal. Informed written consent was obtained from every patient.

3.1 Statistical Analysis

Analysis was done using SPSS version 17 software (SPSS Inc., Illinois, Chicago, USA). Numerical variables were summarized as mean/standard deviation and categorical variables as count/percentages. Each variable from anthropometric and craniofacial parameters was correlated for association separately to each parameter of severity of OSA, i.e., AHI, nadir oxygen and percent of total time with oxygen saturation level lower than 90% during sleep ($T<90\%$). Chi square test, Kruskal–Wallis test and Mann–Whitney *U* test were applied for testing the level of significance appropriately for nominal, numerical data and categorical variables p values ≤ 0.05 were considered as statistically significant.

4 Result

Total 242 patients underwent level I PSG during the study period. Of these, 193 patients constituted final study population after inclusion criteria were met. There were total 148 (76.68%) males and 45 (23.31%) females in study group with ratio 3.28:1. Mean age (with 95% CI) of cohort was 50.24 ± 1.65 years (min–max range 25–82). Mean AHI was 53.84 ± 4.81 (range 5.40–136.6) in 193 patients. Data of 184 patients were available for nadir oxygen levels and mean nadir oxygen saturation was 80.26 ± 2.05. Data of 182 patients was available for percent of total time with oxygen saturation level lower than 90% during sleep ($T<90\%$); mean $T<90\%$ was 8.56 ± 2.48. Mean BMI of cohort was 30.20 ± 0.84. As per Asian Indian cut off of obesity by BMI (≥ 25 kg/m^2), 158 (81.8%) were obese while as per WHO criteria (BMI ≥ 30 kg/m$^{2)}$ 89 (46.1%) were found to be obese (Table 1).

Retrognathia, micrognathia, macroglossia, high arched palate, cross bite, high neck circumference, nasal valve dehiscence and long uvula was seen in 10.9, 18.7, 71.5, 19.7, 12.4, 26.4, 24.9, and 25.9%, respectively. Tonsil grade 3 or 4 was seen in only 6.3%. Modified Mallampati grades 3 and 4 were seen in 26.4 and 53.9%, respectively.

With respect to all three severity markers of OSA, i.e., AHI, nadir oxygen and $T<90\%$, statistically significant correlation was found for modified Mallampati class (p value 0.001, 0.009, and 0.002, respectively), waist circumference (p value 0.002, <0.001, and 0.001, respectively), neck circumference (p value <0.001, <0.001, and <0.001, respectively) and BMI (both WHO and Asian Indian cut off). Age, retrognathia, macroglossia, long uvula, high arched palate, nasal valve collapse, and cross bite did not have any statistically significant correlation with OSA severity.

Mann–Whitney *U* test showed that females and patients with higher waist/hip ratios had lower nadir oxygen levels ($p=0.027$ and 0.047, respectively). Micrognathia correlated statistically significantly with only AHI ($p=0.037$) using Mann–Whitney *U* test. Similarly, increasing tonsillar grades correlated significantly with AHI using Kruskal–Wallis test ($p=0.034$).

5 Discussion

Obesity is usually considered the most important culprit in the development of OSA, but craniofacial abnormalities also have been proven as crucial risk factors [4]. Obstruction due to various structures such as tonsils, posterior pharyngeal wall, enlarged tongue, enlarged uvula, palate, nasal structures plays a contributory role with varying impact and degree in individual patients [24]. Various ethnic groups differ in terms of body skeletal, soft tissue and craniofacial features which affect upper airway cross sections and caliber, and thus lead to apneic events during sleep [8]. Even amongst Asians with OSA, craniofacial morphology dissimilarity was shown in different ethnic groups (i.e., Malay, Indian and Chinese) [25]. Due to scarcity of data from Indian population, this study was done to find out prevalence and effect of various craniofacial abnormalities in OSA patients. This study shows that some of the craniofacial abnormalities and obesity indicators are associated with OSA severity and also that simple clinical examination could help in screening of patients who are more likely to have severe disease.

Macroglossia is considered to be an indicator of crowded airways which leads to impression of teeth over tongue. In our study, it was seen in almost ¾ of the patients but surprisingly it did not have any effect on severity of OSA. Similarly, higher (3 and 4) modified Mallampati class was seen in 80% of our sample size, and interestingly, it was the only variable which had positive correlation with all variables of severity of OSA. Individuals with high modified Mallampati scores are more prone for obstructions because of crowed oropharynx which hinders airflow to lower airways [24]. There is enough data to support that the presence of higher Mallampati class predicts severe OSA amongst OSA patients [24, 26, 37]. In a Brazilian study, both AHI and nadir oxygen saturation correlated with modified Mallampati class [32]. An Australian study [36] found similar results with positive

Table 1 Comparison of craniofacial abnormalities with severity of Obstructive sleep apnea

Variable		AH I					Nadiroxygen					*T*<90%				
		Valid *N*	Column valid *N* %	Mean	Standard deviation	*p* value	Valid *N*	Column valid *N* %	Mean	Standard deviation	p value	Valid *N*	Column valid *N* %	Mean	Standard deviation	*p* value
Age group (years)	<50.0	94	48.7%	54.8	35.9	0.848	87	47.3%	80.9	14.8	0.195	87	47.8%	9.7	18.6	0.68
	>50.0	99	51.3%	52.9	32.0		97	52.7%	79.7	13.5		95	52.2%	7.5	15.4	
Gender	Female	45	23.3%	53.9	34.5	0.983	45	24.5%	76.3	16.3	0.027	44	24.2%	11.7	20.0	0.091
	Male	148	76.7%	53.8	33.8		139	75.5%	81.6	13.1		138	75.8%	7.6	15.9	
Retrognathia	No	172	89.1%	53.0	33.3	0.383	165	89.7%	80.4	13.9	0.936	163	89.6%	7.9	16.2	0.541
	Yes	21	10.9%	60.7	38.6		19	1 0.3%	79.3	16.0		19	10.4%	14.0	22.7	
Micrognathia	No	157	81.3%	51.3	32.7	0.037	149	81.0%	80.9	14.1	0.129	147	80.8%	7.4	15.8	0.089
	Yes	36	18.7%	65.1	37.1		35	1 9.0%	77.6	14.1		35	19.2%	13.4	20.7	
Macroglossia	No	55	28.5%	55.3	35.2	0.804	53	28.8%	80.3	12.9	0.662	53	29.1%	8.9	16.5	0.69
	Yes	138	71.5%	53.3	33.4		131	71.2%	80.3	14.6		129	70.9%	8.4	17.2	
Modified mallampatti class	1.0	10	5.2%	29.9	14.9	0.001	10	5.4%	87.6	5.1	0.009	10	5.5%	.1	.2	0.002
	2.0	28	14.5%	40.6	31.2		27	14.7%	84.5	11.6		26	14.3%	6.1	14.2	
	3.0	51	26.4%	50.8	33.5		46	25.0%	82.9	11.3		45	24.7%	8.3	18.6	
	4.0	104	53.9%	61.2	34.0		101	54.9%	77.2	15.7		101	55.5%	10.2	17.6	
Tonsil grades	0.0	63	32.8%	45.1	33.8	0.034	58	31.7%	81.5	13.6	0.879	57	31.5%	7.1	16.2	0.545
	1.0	70	36.5%	56.6	31.2		68	37.2%	79.7	15.4		67	37.0%	9.5	18.1	
	2.0	47	24.5%	59.7	36.2		45	24.6%	79.9	12.8		45	24.9%	8.0	14.8	
	3.0	9	4.7%	69.9	34.9		9	4.9%	77.6	16.2		9	5.0%	11.0	23.7	
	4.0	3	1.6%	34.4	29.6		3	1.6%	81.3	11.8		3	1.7%	19.7	22.8	
Long uvula	No	143	74.1%	52.8	33.9	0.453	136	73.9%	81.2	13.6	0.136	134	73.6%	7.2	15.5	0.063
	Yes	50	25.9%	56.8	34.0		48	26.1 %	77.5	15.1		48	26.4%	12.5	20.3	
High arched palate	No	155	80.3%	54.4	33.8	0.633	146	79.3%	80.8	13.7	0.368	144	79.1%	8.4	17.1	0.937
	Yes	38	19.7%	51.5	34.4		38	20.7%	78.3	15.5		38	20.9%	9.0	16.7	
Nasal valve collapse	No	145	75.1%	56.0	34.7	0.151	136	73.9%	79.9	14.6	0.78	134	73.6%	9.2	17.5	0.473
	Yes	48	24.9%	47.2	30.7		48	26.1 %	81.4	12.7		48	26.4%	6.8	15.6	
Cross bite	No	169	87.6%	54.0	33.4	0.69	160	87.0%	81.3	12.9	0.122	158	86.8%	7.7	16.1	0.385
	Yes	24	12.4%	52.4	38.0		24	1 3.0%	73.4	19.4		24	13.2%	14.1	21.7	
Central_obesity	No	20	10.4%	33.4	26.8	0.002	20	1 0.9%	89.3	5.6	<0.001	20	11.0%	1.0	3.7	0.001
	Yes	173	89.6%	56.2	33.9		164	89.1 %	79.2	14.4		162	89.0%	9.5	17.7	
Neck circumference	Normal	142	73.6%	46.6	31.5	<0.001	138	75.0%	83.1	11.3	<0.001	136	74.7%	4.6	11.9	<0.001
	Abnormal	51	26.4%	74.1	32.1		46	25.0%	71.6	17.9		46	25.3%	20.2	23.5	
Waist-hip ratio	Normal	22	11.4%	45.4	34.1	0.162	21	11.4%	84.3	13.7	0.047	20	11.0%	5.3	15.4	0.102
	Abnormal	171	88.6%	54.9	33.8		163	88.6%	79.7	14.1		162	89.0%	9.0	17.2	

Table 1 (continued)

Variable		AH I					Nadiroxygen					$T<90\%$				
		Valid *N*	Column valid *N* %	Mean	Standard deviation	*p* value	Valid *N*	Column valid *N* %	Mean	Standard deviation	p value	Valid *N*	Column valid *N* %	Mean	Standard deviation	*p* value
BMI (Asian Indian)	Less than 25	35	18.1%	35.7	23.8	0.001	35	1 9.0%	87.3	7.8	<0.001	34	18.7%	1.2	3.4	<0.001
	≥25	158	81.9%	57.9	34.5		149	81.0%	78.6	14.7		148	81.3%	10.3	18.4	
BMI (WHO)	Non-obese(<30)	104	53.9%	42.4	29.1	<0.001	100	54.3%	84.9	9.6	<0.001	99	54.4%	3.0	8.5	<0.001
	Obese(≥30)	89	46.1%	67.2	34.3		84	45.7%	74.8	16.5		83	45.6%	15.2	21.6	

Coefficients[a]

Model		Unstandardized coefficients	Standardized coefficients		*t*	Sig.	95.0% Confidence interval for B	
		B	Std. error	Beta			Lower bound	Upper bound
1	(Constant)	−20.653	11.428		−1.807	0.072	−43.194	1.889
	BMI	2.466	0.371	0.433	6.643	0.000	1.734	3.199

NC > 16 inches in females and > 17 in females considered abnormal

Waist/hip ratio > 0.90 cm (males); > 0.85 cm (females) was considered abnormal

[a] Dependent Variable: AHI

correlation of modified Mallampati class with severity of OSA, however, they concluded that ''Mallampati class IV is not useful in *ruling in* patients with severe OSA and Mallampati class I is not useful in *ruling out* OSA in the sleep clinic population''. Similarly, it was found in our study that although patients with higher Mallampati grades had severe OSA, but even OSA patients with lower Mallampati grades 1 and 2 also had mean AHI of 29.9 and 40.6, respectively, which means that even lower Mallampati grades have mean AHI of severe OSA and lower Mallampati cannot be used to rule out severe OSA. Although this study was done in only OSA population, thus it cannot be extrapolated to ruling out severe OSA in general population.

In our study, higher tonsillar grades and micrognathia were associated with higher AHI and thus with more severe OSA. One study found the correlation of tonsillar size with AHI, however, in another study, no correlation was found between tonsil grades and AHI [27, 28]. None of the other clinical craniofacial variables in our study was shown to be associated with severity of OSA. However, retrognathia has been shown to be associated with higher AHI in few studies [29, 30] but no correlation was seen in another study.

Conventionally, male gender is considered the risk factor for OSA, [31, 32] but in our study, there was no difference in AHI or $T<90\%$ in males and females. Since our sample study consists of only OSA patients, thus probably this could be explained. Moreover, females had significant lower nadir oxygen in this study.

Studies have shown association of older age with AHI [33–35], but in our study and few other studies, no correlation of age was seen [32, 36, 37]. An American study found that prevalence of OSA increases with age but its severity, both in terms of AHI and nadir oxygen levels decreases with age, i.e., more severe in young ages. [38].

Various anthropometric measurements such as BMI, NC, WC, WHR are used for grading obesity. Obesity has been divided into visceral (WHR > 1) and peripheral types (WHR < 1) and visceral obesity has been shown to be associated with higher cardiovascular complications [11] and with OSA [39]. NC is identified as parameter of central obesity [40] and increased NC causes greater soft tissue around upper airway, causing reduced upper airway cross-section predisposing to OSA [4] [2]. Visceral obesity also leads to reduced lung volumes causing diminished tracheal tug and decreased upper airway cross-section and thus leading to OSA [42???]. In our study, BMI, WC, and NC had strong correlation with AHI, nadir oxygen and $T<90\%$, and WHR ratio had significant correlation with only nadir oxygen.

Level I PSG is gold standard for diagnosis of OSA but it is costly as well as technically demanding procedure particularly in settings of resource limited countries such as ours. Thus, proper selection of patients is of utmost importance for PSG. Level III PSG is more readily available compared to Level I in India where only 300 Level I PSG machines are available compared to 5000 level III PSG machines. Thus, if patient has higher modified Mallampati grades, micrognathia, large tonsils or BMI > 30 kg/m^2, higher NC, WC or WHR, then chances of having more severe OSA are higher. Level III PSG usually underestimates AHI due to various factors such as (1) unavailability of EEG channels thus inability to mark arousals for scoring hypopneas and (2) overestimation of total sleep time. Level III PSG has been recommended in patients with high pretest probability of moderate to severe OSA. Therefore, doing level III PSG in patients with these craniofacial or anthropometric characteristics probably would not lead to false negative cases since the presence of these variables signifies more severe OSA. Thus, we propose that level III PSG should be done in suspected OSA patients having these craniofacial and anthropometric abnormalities besides good clinical history. In addition, simple initial clinical craniofacial and anthropometric assessment can have impact on treatment approaches including use of oral and dental appliances and surgical management.

6 Conclusion

Anthropometric and craniofacial variables are easy to perform clinical examinations. Higher modified Mallampati class, WC, NC, BMI, large tonsils and micrognathia are associated with more severe OSA.

Funding None.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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

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