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Assessment of the Craniofacial and Cervical Parameters using standardized photography in individuals with Obstructive Sleep Apnea

ORIGINAL

Cauby Maia Chaves Jr[1], Marjorie Parente Teles[2], Pedro Felipe Carvalhedo de Bruin[3], Veralice Meireles Sales de Bruin[3], Marcela Lima Gurgel[4], Rowdley Robert Pereira Rossi[5], Paulo Afonso Cunali[6], Otávio Ferraz[7], Lia Bittencourt[8].

1 DDS, MSc, PhD, Associate Professor, Orthodontics Discipline, Department of Clinical Dentistry, Dental School, Federal University of Ceará, Fortaleza, CE, Brazil.
2 DDS, MSc, Dental School, Federal University of Ceará, Fortaleza, CE, Brazil.
3 MD, PhD, Associate Professor, Department of Medicine, Federal University of Ceará, Fortaleza, CE, Brazil.
4 Scholarship Student, Department of Clinical Dentistry, Dental School, Federal University of Ceará, Fortaleza, CE, Brazil.
5 Doctorate Student, Department of Pneumology, Federal University of São Paulo, Brazil.
6 DDS, PhD, Professor of the Department of Dentistry, Federal University of Paraná, Brazil.
7 DDS, Research at the Sleep Medicine and Biology Discipline, department of Psychobiology, Federal University of São Paulo, Brazil.
8 MD, MSc, PhD, Adjunct Professor, department of Psychobiology, Federal University of São Paulo, Brazil.

Contact information:

Cauby Maia Chaves Jr.

cmcjr@uol.com.br

Abstract

Objectives: The purpose of this study was to use standardized digital facial photography to investigate craniofacial and cervical characteristics of individuals with obstructive sleep apnea (OSA) and the possible associations between these characteristics and polysomnographic data.

Material and methods: The final sample included 50 individuals with OSA (Apnea Hypopnea Index - AHI $\geq$ 5) and 10 controls (AHI < 5). All subjects underwent a history and physical examination with measurements of anthropometric parameters and overnight polysomnographic records. Anthropometric assessment and standardized frontal-profile facial photographs were performed prior to polysomnography.

Results: Higher AHI was associated with alterations in the cervical area, where the neck circumferences were significantly increased. We observed an interaction between the craniofacial and anthropometric variables with the polysomnographic variable. Specifically, when there was increased superior facial third (P=0.032), inferior facial third (P=0.039) and cervical circumference (P=0.050), there was a greater chance of having AHI over 5.

Conclusions: Using craniofacial measurements in standardized photographs and anthropometric measurements, the vertical facial pattern and the neck circumference are the strongest predictors of OSA.

Keywords
Obstructive sleep apnea, facial photographs, craniofacial characteristics, polysomnography.

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Introduction

Obstructive sleep apnea (OSA) is characterized by episodes with partial or total obstruction of the upper airways during sleep[1]. This sleep disorder is often associated with snoring and obesity. Furthermore, affects 2 to 4% of the population; mostly men aged 40 to 60 years[2]. The development of sophisticated diagnostic tools and the increased awareness of this disease among medical professionals and the population in general have made the diagnosis of new OSA cases more common, significantly increasing its prevalence. OSA has been considered a public health problem since 1993 [3,4].

The pathophysiology of obstructive sleep apnea syndrome is multifactorial. Gender and obesity, as well as genetic, anatomic, and hormonal factors, together with changes of ventilatory drive, interact in a diverse manner in the pathophysiology and clinical expression of this disease. The increase of the body mass index and neck circumference are strong predictors of the disease [5,6].

After the early 1980s, cephalometry began to be frequently used in the study of OSA, as an effort to identify the anatomic craniofacial determinants involved in the pharyngeal collapse during sleep[7-11]. Despite some controversies in the literature, the craniofacial characteristics that have been reported to be associated with the occurrence and severity of OSA include: long face, mandibular retroposition, shortening of the mandibular body, and inferior displacement of the hyoid bone and ogival palate[12-14].

The aims of this study were to evaluate standardized digital facial photos from a group of individuals who were referred to receive polysomnography, and to evaluate the interaction among craniofacial, anthropometric and polysomnographic findings. The standardized digital facial photos were taken to investigate the external craniofacial characteristics, the facial pattern and possible alterations in their cervical region.

Material and method

Consecutive individuals referred for a full-night, in-laboratory polyssomnographic with suspected sleep-related breathing disorders were invited to participate in this study. In total, 60 individuals of both genders ranging from 23 to 75 years of age were prospectively evaluated with standard polysomnography. Fifth individuals were confirmed to have apnea hypopnea index (AHI) over 5 (OSA group), and 10 individuals were found to have AHI under 5 (control group). The following were the exclusion criteria for this study:

- Subjects who presented AHI less than 5 but who snored
- loss of subsequent dental support (loss of upper and lower molars)
- previous orthodontic treatment
- orthognatic or airways surgical treatment
- history of syndromal craniofacial abnormalites
- previous use of any drugs that would induce or reduce sleep
- presence of chronic obstructive pulmonary diseases
- neurological or psychiatric disease or other primary sleep disorders

The photographic and anthropometric procedures were performed on all individuals on the same day as the polysomnography. All analyses photographic and data collection were carried out by a single investigator who blinded to the result of the polyssonography. Ethics approval was obtained from the institutional ethics committee, and written informed consent was obtained from all individuals.

Anthropometric data assessment

Information on gender, age, height, weight and cervical circumference was collected for each individual. The body mass index (BMI) was calculated by dividing the individual's weight by the square

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of his height (Kg/m^2). The neck circumference (NC) was measured at the level of the cricothyroid membrane[15], with the patients standing.

Facial assessment

Two facial pictures of each individual were taken (frontal and a profile pictures) with a digital photographic camera (coolpix 4500 - Nikon), mounted on a tripod, with its lens guided vertically, under the fixed distance of 1.2 m from the individual. For the frontal picture, the individuals were standing up. They were instructed to maintain their heads in a natural posture while looking at the camera lens in front of them. For the profile picture, the individuals were also standing up with their heads in natural postures, with the right side of the face turned towards the operator. For the evaluation of the variables, a program of computerized facial analyses was used (Cef X 2000 - CDT). The following lineal and angular measures (**Figures 1 and 2**) were taken:

- Tr-Gla: union between trichio and glabela (upper facial third).
- Gla-Sn: union between glabela and subnasal (middle facial third).
- Sn-Me: union subnasal and mentonian (lower facial third).
- Go-Me: union gonion and mentonian (mandibular length).
- Ce-Me: union point neck-throat and mentonian (line chin-neck).
- Gl-Sn-Me: obtained angle of the intersection of the line Gla-Sn and Sn-Me (Angle of the convexity of the profile).

Natural Head position is used increasingly as a logical reference for evaluation of craniofacial morphology and has been show to be stable and reproducible[16] .

Diagnostic polysomnographic

The entire night polysomnographic study (PSG), carried out in the laboratory under the supervision of a qualified polysomnography technician, constitutes the standard diagnostic method for the evaluation of respiratory sleep disorders[1,5]. All patients underwent an in lab full-night polysomnography (Alice; Chest Ltd, Japan) including electroencephalography (EEG), electromyography (EMG), electrooculography (EOG), electrocardiography (ECG), airflow using the oronasal thermistor, thoracic and abdominal respiratory movements with Piezo electric sensors, oxygen saturation using pulse oximeter and snoring. A record of at least 6 hours was recommended. The episodes of apnea were defined as the complete

Figure 1: Frontal view

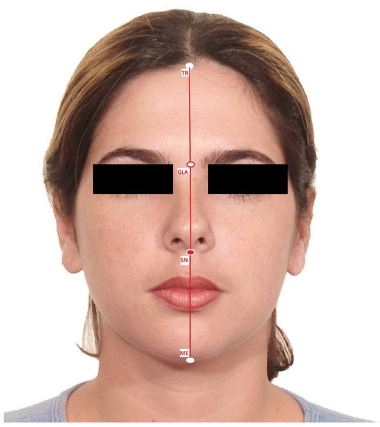
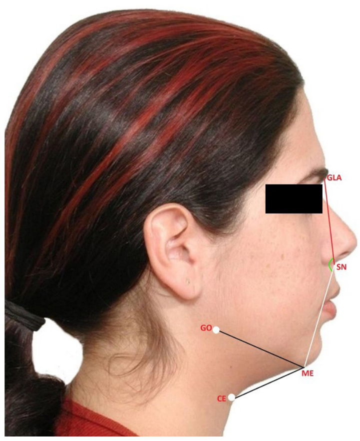


Figure 2: Profile view



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airflow cessation for >10 seconds with oxygen desaturation of at least 4% and/or associated with arousal. Hypopnea was defined as more than 50% reduction in the oronasal airflow for >10 seconds accompanied by reduction in oxygen saturation of at least 4% and/or by an arousal. The apnea hypopnea index (AHI) was calculated as the sum of total respiratory events of apnea and hypopnea per hour of sleep. The cut-off of the apnea-hypopnea index (AHI) used was five obstructive events / hours of total sleep time. The OSA cases were defined by an AHI $\geq$ 5 events per hour. The controls were defined by an AHI < 5 events per hour.

Statistical analysis

The intra-examiner reliability test was used to determine the errors in measurements and calculated the Spearman coefficients. Photographs from 11 subjects were used in reliability study. Each of the 11 photographs was traced and measured twice.

The results are presented as means, standard deviations, maximal and minimal values for the anthropometric, polysomnographic and craniofacial variables. For identification of factors that predicted AHI over 5, univariate and multivariate logistic regression models were used. The dependent variable was AHI > 5. The independent variables analyzed were Tr – Gla, Gla – Sn, Sn – Me, Go – Me, Ce-Me, BMI, and neck circunference. Statistical significance was defined as $p < 0.05$. Firstly, simple univariate logistic regression models were used to identify variables that were significant candidate predictors of AHI over 5. Second, all the candidate variables were considered in multivariate logistic regression models. A backward stepwise procedure was used to identify and eliminate variables that did not make an individual contribution in the multivariate model to improve parsimony.

Results

Spearman correlation indicated intra-observer agreement of 0.97 for Sn-Me and Go-Me; 0.94 for Tr-Gla, Gla-Sn and Ce-Me; and 0.92 for Gl.Sn.Me. Values greater than 0.90 indicate excellent reliability.

The anthropometric, polysomnographic and facial data of the sample are shown in **Table 1**. The age showed no significant differences between the groups with AHI over and under 5. The gender ratio of men to women in the prevalence of AHI over 5 was 3:1. The values of cervical circumferences were significantly different between groups AHI over and under 5.

The three measurements of Tr-Gla, Gla-Sn, Sn-Me were significantly different when groups with AHI over and under 5 were compared (**Table 1**).

The mean values of the upper facial third in the group with or without AHI over 5 were 63.59 mm ± 8.05 and 54.96 mm ± 9.47 respectively. The mean values for the middle facial third, in the group with AHI over and under 5 were 84.11mm ± 8.21 and 76.45mm ± 10.14, respectively. The mean values of the lower facial third in the group with AHI over and under 5 were 87.73mm ± 11.83 and 75.51mm ± 7.53, respectively.

After the identification of the univariate predictors, multivariate analysis was carried out with the variables identified in the previous analysis (**Table 2**). A backward stepwise procedure was used to identify and eliminate variables that do not have an individual contribution in the univariate model to improve the parsimony. The Gla – Sn, Go – Me and BMI variables were eliminated by the stepwise procedure.

To facilitate their uses in the clinical setting, variables in the multivariate models were dichotomized. The cut-offs, 95% confidence intervals and statis-

Table 1. General Characteristics of the 60 Individuals (10 with AHI <5 And 50 with AHI ≥5)

Variables	AHI < 5	Mín.	Máx.	AHI ≥ 5	Mín.	Máx.	p
Tr – Gla (mm)	54.96 ± 9.47	39.13	69.09	63.59 ± 8.05	48.59	82.30	< 0.05*
Gla – Sn(mm)	76.45 ± 10.14	61.1	91.47	84.11 ± 8.21	72,24	101.711	< 0.05*
Sn – Me(mm)	75.51 ± 7.53	65.12	88.43	87.73 ± 11.83	69,13	122.06	< 0.05*
Ce – Me(mm)	31.91 ± 3.71	23.88	34.96	38.58 ± 11.47	23,49	66.15	< 0.05*
GlA-Sn-Me(O)	155.99 ± 3.82	151.91	160.55	154.54 ± 4.02	143.27	164.65	> 0.05
Go – Me(mm)	81.20 ± 5.41	72.16	87.69	89.62 ± 9.61	72.33	118.68	< 0.05*
SpO2min (%)	89 ± 1.81	85	92	77 ± 7.09	57	89	< 0.05*
SpO2<90% (min)	2.05 ± 1.71	0.00	4.50	55.14 ± 57.60	0.50	211.00	< 0.05*
age (years)	46.90 ± 12.39	30.00	65.00	50.74 ± 13.18	23.00	75.00	> 0.05
gender (♂/♀)	7♂/3♀	-	-	38♂/12♀	-	-	-
BMI (kg/m2)	23.19 ± 2.36	18.30	25.80	30.70 ± 6.47	19.50	42.60	< 0.05*
neck Circ.(mm)	35.40 ± 3.03	30.00	39.00	40.88 ± 4.23	31.00	50.00	< 0.05*

Legends: Tr-Gla (upper facial third), Gla-Sn (middle facial third), Sn-Me (lower facial third), Ce-Me (chin-neck length), Gla-Sn-Me (angle of profile convexity), Go-Me (mandibular length), SpO2min (minimum oxygen saturation), SpO2 <90% (minimum oxygen saturation less than 90%), BMI (body mass index), Neck Circ. (neck circumference). *p <0.05.

Table 2. Univariate Analysis of Apnea Predictors

Variables	Odds Ratio	p	Confidence Interval (95%)
Tr – Gla (mm)	1.144	0.010*	1.032 - 1.268
Gla – Sn(mm)	1.127	0.021*	1.018 - 1.247
Sn – Me(mm)	1.190	0.004*	1.058 - 1.338
Ce – Me(mm)	1.090	0.092	0.986 - 1.205
GlA.Sn.Me (^{O})	0.910	0.296	0.762 - 1.086
Go – Me(mm)	1.139	0.015*	1.026 - 1.264
AGE(years)	1.023	0.394	0.971 - 1.077
BMI(kg/m^2)	1.531	0.005*	1.136 - 2.063
Neck Circ. (mm)	1.414	0.002*	1.130 - 1.770

* p < 0.05

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tical significance are shown in **Table 3**. The model was then formed by the following variables: Tr-Gla (upper facial third), Sn-Me (lower facial third) and N.C (neck circumference) according to **Table 4**. Therefore, according to the model, the probability of an individual having AHI over 5 can be estimated by the following equation:

$$P = \frac{1}{1 + e^{-(-2,738 + 3,065X_1 + 2,070X_2 + 2,484X_3)}}$$

where e =2.71; x_1; x_2 and x_3 are the dichotomized variables Tr-Gla, Sn – Me and C.C, respectively. The model had a 70% sensitivity and 100% specificity. The margin of error was 5%. Thus, according to this model, the absence of the three variables led to a probability of AHI over 5 of only 6.08%, while the presence of the three variables was associated with a probability of 99.25% for AHI over 5.

Discussion

Although cephalometry is the gold standard method to characterize craniofacial morphology, there is a lack of consensus in the literature about the correlation between craniofacial measurements in cephalometry and the occurrence of OSA. Methods that use standardized photos and facial analysis have been increasingly considered in daily clinical practice[17-20]. Some of the face features are related to the morphology of hard tissues; therefore, standardized photos may become a useful tool in the characterization of craniofacial morphology. Recent studies have been conducted that make use of digital photography to investigate facial and cervical characteristics that seem to be correlated with OSA[16,21-23].

Our study investigated how facial and anthropometric parameters correlate with OSA, and which

Table 3. Analysis of the ROC curve of the variables in the multivariate model

	Cut-off point	Area	CIC 95% Area		P
Tr-Gla(mm)	45.00	0.784	0.578	0.990	0.005
Sn – Me(mm)	78.50	0.818	0.681	0.955	0.002
Neck Circ.(mm)	37.50	0.882	0.795	0.969	0.000

Table 4. Multivariate analysis of apnea predictors. The columns represent variables, odds ratios, 95% confidence intervals and p-values.

Variables	Odds Ratio	p	Confidence Interval (95%)
Tr-Gla(mm)	1.264	0.032	1.020 – 1..67
Sn – Me(mm)	1.522	0.039	1.022 – 2.266
Neck Circ(mm)	3.016	0.050	1.000 – 9.098

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of these parameters could be used to predict OSA. A recurrent finding in the literature has been that OSAS is predicted by a convex profile[9,24,25]. Studies have reported that convex profiles with reduced mandibular lengths may lead to decreases in the posterior-inferior airway space, contributing to the development of OSA. The current study sample was exclusively composed of individuals with profile convexity angles that were smaller than 165° in both groups with AHI over and under 5. No statistically significant differences were found between the two groups in this study, and therefore, the convex profile was excluded as a predictor of OSA.

Another measurement obtained from the individual's profile was the jaw-neck line (Ce-Me). The length of this line is generally 40 mm ± 5 mm[38]. In this sample, most individuals with AHI over 5 had values lower than 35 mm (58.33%), and this confirms previous reports that the shortening of the mandibular body is predictive of OSA[25].

The Go-Me measurement, which refers to mandibular length, was also assessed. There was a statistically significant difference between the groups with AHI over and under 5. However, in the group with AHI over 5, the measurements were paradoxically higher on average than those in the group with AHI under 5. This data was in disagreement with most findings in the literature that pointed to decreased mandible lengths as predictors of OSA[11,21,26]. This may be explained by the fact that, although there was little measurement error, the demarcation of the Go point (the vertex of the angle of the mandible) may have been faulty in facial photographs. This limitation was detected by Zhang et al.[20], whose work showed that the repeatability of the point could be improved when it was directly demarcated on the individual's face before taking the facial pictures.

Our results were in agreement with the findings of other studies that showed a high prevalence of the disease in the 4th and 5th decades of life[3,12] and that men as strong candidates to have apnea[3,27].

Corroborating the findings of previous studies[26,28], the BMI showed significant differences between the groups with AHI over and under 5 , pointing for the risk factor of obesity in the physiopathology of OSA. Increasing cervical circumferences were correlated with obstructive respiratory sleep disorder, which was consistent with the literature[29]. Kushida, Bradley and Guilleminault[28] set the cut-off value of neck circunference at 40 cm to differentiate patients with and without OSA. Consistent with their findings, the mean neck circunference in patients with AHI bellow 5 was 35.4 cm and in patients with AHI over 5, the mean values were over 40 cm.

All values of vertical facial measurements in this study were higher in the group with AHI over 5, indicating that a long face may contribute to the narrowing of the upper airways space[7,11,12,24,30]. Our predictive model for AHI over 5 indicated that the larger the measures of Tr-Gla, Sn-Me and N.C., the greater would be the likelihood of having OSA. This equation showed that AHI was explained, at least partially, by the interaction of craniofacial and anthropometric variables. This findings was in disagreement with a study accomplished by Lee et al.[21], which demonstrated no significant differences in the vertical dimensions of the face.

In summary, the most relevant external characteristics for prediction of AHI increase were increased vertical craniofacial measurements in the upper and lower facial thirds. The increases of these craniofacial measurements pointed to a vertical facial pattern, indicating a characteristic long face for individuals with obstructive sleep apnea. Individuals with OSA also presented alterations in the cervical region, as evidenced by the significantly larger neck circumferences. An interaction of the craniofacial and anthropometric variables was also noted in relation to the polysomnographic variables representing the number of respiratory pauses per hour of sleep (AHI). The greater the upper facial third, the lower facial third and the cervical circumference, the greater was the chance of an individual having OSA.

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Conclusion

Using craniofacial measurements in standardized photographs and anthropometric measurements, the vertical facial pattern and the neck circumference are the strongest predictors of OSA.

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