Sex differences in anthropometric and cephalometric characteristics in the severity of obstructive sleep apnea syndrome

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Introduction: Craniofacial anatomic abnormalities related to structural narrowing of the upper airway have been reported in patients with obstructive sleep apnea syndrome (OSAS). The purpose of this study was to test whether there are sex differences in the relative contributions of specific anthropometric and cephalometric measurements of OSAS severity. **Methods:** The subjects were Taiwanese patients who visited the Ear, Nose, and Throat Department of National Taiwan University Hospital with complaints of snoring or sleep apnea. The anthropometric, cephalometric, and overnight polysomnographic records of 109 subjects were evaluated. **Results:** There are obvious sex differences in the craniofacial skeletal characteristics that contribute to OSAS severity. Male patients with the following risk factors are likely to have more severe type OSAS: increased neck size, inferiorly positioned hyoid bone, and greater anterior lower facial height. The risk factors related to the severity of OSAS in female patients include smaller posterior facial height and anteriorly positioned hyoid bone. **Conclusions:** To evaluate OSAS severity, different anthropometric and cephalometric measurements should be used for men and women. The craniofacial skeletal characteristics that contribute to OSAS severity were in the anterior lower portion of the profile in men and in the posterior portion of the profile in women. (Am J Orthod Dentofacial Orthop 2009;135:155-64)

Sleep-disordered breathing, characterized by repeated episodes of hypopnea (underbreathing) and apnea (not breathing) during sleep, affects 24% of middle-aged white men in Wisconsin,¹ 14.4% of Chinese men in Hong Kong,² and 27% and 16% of middle-aged Korean men and women, respectively.³ Obstructive sleep apnea syndrome (OSAS) is a common form of sleep-disordered breathing that is characterized by repetitive episodes of partial or complete upper airway obstruction, causing sleep fragmentation and other symptoms.⁴ OSAS is equally common among middle-aged white and Hong Kong Chinese populations with a minimum prevalence of 4%.^{1,2}

Approximately 40% to 60% of OSAS patients seen in sleep laboratories have hypertension.^{5,6} There is also an association of OSAS with heart failure,⁷ ischemic heart disease,⁸ stroke,⁹ cardiac arrhythmia,¹⁰ and sudden cardiac death.¹¹ These findings clearly show that OSAS is a serious condition with major health-related consequences and that identification of patients with OSAS is important.

Although still under investigation, increased pharyngeal collapse during sleep has been postulated to contribute as a risk factor for OSAS.^{12,13} Craniofacial anatomic abnormalities related to structural narrowing of the upper airway have been reported in patients with OSAS.¹⁴⁻²⁰

One overnight polysomnogram in a sleep laboratory is an adequate measure and is accepted as the gold standard for diagnosis of OSAS. Although the diagnostic superiority of polysomnography is without question, it is regarded as both time consuming and expensive. OSAS is a progressive disease that evolves from snoring.²¹ This evolution moves along a spectrum of heavy snoring with intermittent apneic events, eventually progressing to severe disease with respiratory failure in extreme cases. Early diagnosis of OSAS is important for minimizing neurocognitive, cardiac, behavioral, and developmental complications as a result of the syndrome.²² Therefore, there is a need for a

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simple, rapid, and effective diagnostic tool that can be used to differentiate patients with simple snoring from those with OSAS. Several methods exploiting advanced technologies have been used to evaluate the anatomic characteristics of the upper airway and the craniofacial structures that might predict OSAS and determine the sites of obstruction.²³⁻²⁷ However, the traditional cephalometric method has been the most practical.^{14,15,18,19,28-32}

Although OSAS is prevalent in both sexes, male predominance is clear.^{1,33} The mechanism for the sex difference in OSAS prevalence is an area of intensive research. We hypothesized that the etiology and features of OSAS progression in women differ from those observed in men. This study was conducted to evaluate the potential sex differences in anthropometric and cephalometric variables that predict risks associated with OSAS severity.

MATERIAL AND METHODS

The subjects were Taiwanese patients who visited the Ear, Nose, and Throat Department of National Taiwan University Hospital with complaints of snoring or sleep apnea. Institutional review board approval for the study was obtained from National Taiwan University Hospital, and all patients gave informed consent before entering the study.

All subjects had a full complement of permanent teeth (except for the third molars in some cases), no apparent craniofacial deformities, no history of orthodontic treatment, no history of pharyngeal airway surgery, and clinically acceptable symmetry of the dental arches. Anthropometric, polysomnographic, and cephalometric records for 109 subjects (76 men, 33 women) were used.

Anthropometric variables included age; body mass index (BMI), calculated by dividing weight (kg) by height squared (m^2); and neck size (cm), measured as the neck circumference at the level of the cricothyroid membrane.

The sleep functions of patients were evaluated from overnight polysomnography. Apnea was defined as cessation of breathing for at least 10 seconds. Hypopnea is a decreased effort to breathe of at least 50% less than the baseline and with at least a 4% decrease in oxygen saturation. The respiratory disturbance index (RDI) was calculated as the sum of total events (apnea and hypopnea) per hour ($[\text{apnea} + \text{hypopnea}] / \text{sleep time}$). A diagnosis of OSAS was based on the RDI. OSAS is considered to be an RDI value of more than 5 per hour. The men and women were divided into 4 groups according to their RDI

Fig 1. Anatomic landmark points: 1, sella turcica (S); 2, nasion (N); 3, porion (Po); 4, orbitale (Or); 5, posterior nasal spine (PNS); 6, anterior nasal spine (ANS); 7, Point A (A); 8, Point B (B); 9, incisal tip of the maxillary central incisor with the most anteriorly positioned crown (U1); 10, incisal tip of the mandibular central incisor with the most anteriorly positioned crown (L1); 11, gnathion (Gn); 12, menton (Me); 13, gonion (Go); 14, posterior gonion (GoP); 15, lower gonion (GoL); 16, basion (Ba); 17, articulare (Ar); 18, third vertebra (C3); 19, hyoidale (H).

values. Subjects who snored but had an RDI less than 5 were grouped into the simple-snoring (Si-Sn) group. The severity of OSAS was stratified by the RDI, with mild (Mi-OSAS) considered 5 to 20 per hour, moderate (Mo-OSAS) 21 to 40 per hour, and severe (Se-OSAS) more than 40 per hour.

A standard cephalometric radiograph was obtained for each subject with the teeth in centric occlusion and the Frankfort horizontal plane parallel to the floor at the end of the expiration phase and without swallowing. All cephalometric landmarks were located and digitized by the same investigator (H.-H.T.), with customized software developed for the 2-dimensional morphologic analysis of the anatomy. Definitions of landmarks, reference planes, and cephalometric angular and linear measurements are given in Figure 1. Errors in landmark identification and digitizing method were estimated by examining duplicate tracings of 20 randomly selected patients made 10 days after the originals. Reliability was fairly accurate, with paired *t* tests indicating no significant differences in the duplicate measure-

Table I. Demographic and anthropometric data

Group variable	Si-Sn		Mi-OSAS		Mo-OSAS		Se-OSAS		ANOVA
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
RDI									
M	2.42	1.33	12.82*	4.36	25.95*	4.79	60.65*	21.58	$P < 0.001$
F	1.36	1.55	9.57*	3.78	33.72*	5.00			$P < 0.001$
T test	NS		$P = 0.022$		$P < 0.001$				
Age									
M	41.07	10.55	40.81	9.08	42.15	8.99	42.24	10.18	NS
F	37.73	9.17	38.50	12.37	43.00	6.39			NS
T test	NS		NS		NS				
BMI									
M	24.43	2.78	25.56	2.55	26.80*	2.17	26.70*	2.33	$P = 0.029$
F	21.91	4.56	22.09	2.74	28.20*	2.14			$P < 0.001$
T test	NS		$P < 0.001$		NS				
Neck size									
M	37.95	1.17	39.02*	1.67	39.90*	1.60	40.71*	1.34	$P < 0.001$
F	32.78	1.89	33.50	2.66	36.00*	2.73			$P = 0.013$
T test	$P < 0.001$		$P < 0.001$		$P < 0.001$				

M, Male; F, female; NS, not significant.

T test, comparison between male and female subjects. ANOVA, comparison between the Si-Sn and the treatment groups.

*Statistically significant difference between the Si-Sn and the treatment groups.

ments. The reference points were digitized as coordinates by using customized software. The straight line passing through sella turcica and parallel to the Frankfort horizontal plane was designated the x-axis. The straight line vertical to the x-axis and passing at a right angle through sella was designated the y-axis. Mean values of the x and y coordinates of all reference points as well as means and standard deviations for all measurements were calculated to enable characterization of the sample groups. All measurements were adjusted for magnification factors.

The Student *t* test for independent samples was used to compare the sexes. Intergroup mean differences for each measurement were separately assessed by using analysis of variance (ANOVA), between the 4 groups of subjects. ANOVA was followed by the Dunnett multiple comparisons test. Stepwise regression analysis was used to determine which variables could be included in a regression model. This procedure is useful in isolating a subset of predictor variables that best explain variations in the dependent variable. All regression analyses were done separately for men and women to assess the relative contributions of the various factors to the RDI. To determine whether the variables identified by the regression model differentiated the 4 groups, a discriminant analysis was performed. This procedure develops a discriminant model that attempts to classify each observation into 1 of the 4 groups. All

statistical analyses were performed with the SPSS statistical software package (version 13.0, SPSS, Cary, NC), and a 5% level of significance ($P < 0.05$) was used.

RESULTS

The numbers of men in the Si-Sn, Mi-OSAS, Mo-OSAS, and Se-OSAS groups were 14, 29, 20, and 13, respectively; the numbers of women were 9, 14, 10, and 0, respectively. Therefore the comparisons of the mean values between the sexes were shown only for the Si-Sn, Mi-OSAS, and Mo-OSAS groups.

The anthropometric data are presented in Table I. Neck size and BMI statistically significantly increased with the severity of OSAS in both sexes. In comparisons with the Si-Sn group, the BMI in both sexes, and the neck size in women were significantly greater in the Mo-OSAS group. The neck sizes of the 3 OSAS groups in men were significantly greater than in the Si-Sn group. The neck sizes of men were significantly greater than those of the women in all groups.

Comparisons of the mean values of cephalometric measurements are shown in Tables II and III. The angular measurement, SN to FH, in men statistically significantly increased with the severity of OSAS, whereas C3-H-Me in men decreased with the severity of OSAS. There were no statistical differences in any angular measurements between the sexes in the Si-Sn group; however, with the severity of OSAS, SN to FH, the gonial angle, and C3-H-Me in women

Table II. Comparison of means of cephalometric angular measurements

Angular measurement (°)	Si-Sn		Mi-OSAS		Mo-OSAS		Se-OSAS		ANOVA
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Y-axis									
M	64.29	4.35	66.15	2.94	65.19	3.24	67.42	4.61	NS
F	66.26	2.97	63.75	5.91	63.52	2.70			NS
T test	NS		NS		NS				
SN to FH									
M	5.29	3.08	4.32	2.85	5.24	3.37	3.38	2.93	NS
F	5.34	3.22	9.28*	4.51	10.28*	2.75			$P = 0.017$
T test	NS		$P < 0.001$		$P < 0.001$				
PP to FH									
M	5.49	4.13	4.72	4.06	4.64	2.28	4.21	3.21	NS
F	2.90	2.26	0.59	3.39	0.84	2.89			NS
T test	NS		$P = 0.002$		$P < 0.001$				
MP to FH									
M	26.06	7.85	28.67	5.35	27.12	6.69	30.39	9.25	NS
F	31.12	3.91	29.33	9.96	29.52	3.87			NS
T test	NS		NS		NS				
RP to FH									
M	88.76	5.89	90.31	4.70	90.32	3.32	92.34	4.83	NS
F	91.32	4.23	86.99	8.68	87.50	5.19			NS
T test	NS		NS		NS				
SNA									
M	81.64	6.02	81.21	3.21	83.15	3.37	81.65	3.73	NS
F	81.53	4.85	81.09	5.05	80.04	5.27			NS
T test	NS		NS		NS				
SNB									
M	79.04	3.51	79.43	2.64	79.26	4.45	79.32	4.43	NS
F	78.78	4.71	77.44	6.04	77.34	3.06			NS
T test	NS		NS		NS				
Gonial angle									
M	116.29	8.85	118.34	7.07	116.80	5.97	118.07	7.66	NS
F	119.82	3.90	122.31	5.61	124.04	4.18			NS
T test	NS		NS		$P = 0.002$				
N-S-Ba									
M	129.71	4.00	126.99	5.24	129.26	5.00	126.53	5.05	NS
F	126.48	4.17	129.22	6.78	132.20	4.97			NS
T test	NS		NS		NS				
C3-H-Me									
M	163.54	11.96	162.67	11.04	160.56	13.32	149.78*	17.95	$P = 0.024$
F	159.97	10.60	159.34	18.61	170.50	7.87			NS
T test	NS		NS		$P = 0.039$				

M, Male; F, female; NS, not significant.

T test, comparison between male and female subjects. ANOVA, comparison between the Si-Sn and the treatment groups.

*Statistically significant difference between the Si-Sn and the treatment groups.

became greater than those measurements in men. There were some differences in linear measurements from the results of the ANOVA between the sexes; ANS-Me and H $\perp$ C3-Me in men and ANS-PNS and H-C3 in women statistically significantly increased with the severity of OSAS, and S-Go in women statistically significantly decreased with the severity of OSAS. H $\perp$ MP was the only linear measurement that statistically significantly increased with the severity of OSAS in both sexes.

To compare craniofacial differences between the sexes in the Si-Sn and Mo-OSAS groups, between the Si-Sn and Se-OSAS groups in men, and between the Si-Sn and Mo-OSAS groups in women, the mean positions of each landmark were plotted, connected, and superimposed (Figs 2-5). These provide profile patterns that can readily be compared with and illustrate the relative overall differences between the 2 groups.

The results of the stepwise multiple regression analysis are shown in Table IV with P values and regression

Table III. Comparison of means of cephalometric linear measurements

Linear measurement (mm)	Si-Sn		Mi-OSAS		Mo-OSAS		Se-OSAS		ANOVA
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
N-S									
M	65.64	2.53	65.28	2.99	65.44	3.21	65.52	3.25	NS
F	62.68	2.35	61.66	2.49	63.62	2.78			NS
T test	$P = 0.010$		$P < 0.001$		NS				
N-ANS									
M	54.87	2.26	54.38	2.69	53.82	3.38	53.50	2.98	NS
F	51.41	3.38	49.11	3.29	50.10	3.55			NS
T test	$P = 0.008$		$P < 0.001$		$P = 0.009$				
ANS-Me									
M	65.25	5.03	69.22*	5.35	69.54*	4.65	71.02	6.31	$P = 0.034$
F	66.97	6.17	66.27	4.66	66.54	3.98			NS
T test	NS		NS		NS				
N-Me									
M	118.26	5.41	122.21	6.06	121.45	6.76	122.90	8.39	NS
F	116.94	8.23	111.55	6.49	114.12	6.17			NS
T test	NS		$P < 0.001$		$P = 0.008$				
S-Go									
M	81.20	6.35	82.30	5.90	81.99	4.60	83.38	4.95	NS
F	75.18	5.47	69.52*	4.05	68.58*	5.35			$P = 0.012$
T test	$P = 0.029$		$P < 0.001$		$P < 0.001$				
ANS-PNS									
M	50.19	2.12	48.70	3.52	50.41	3.73	48.59	3.39	NS
F	45.44	1.80	46.21	3.43	48.74*	1.61			$P = 0.021$
T test	$P < 0.001$		$P = 0.034$		NS				
Go-Me									
M	68.10	3.60	68.86	4.77	70.01	5.10	68.79	3.45	NS
F	66.23	3.15	63.74	3.26	65.42	3.50			NS
T test	NS		$P < 0.001$		$P = 0.017$				
Ar-Go									
M	48.51	5.07	48.77	5.33	48.60	3.05	48.19	3.39	NS
F	43.93	4.85	39.89	3.07	42.14	4.23			NS
T test	$P = 0.043$		$P < 0.001$		$P < 0.001$				
S-Ba									
M	44.85	3.36	45.38	2.32	45.32	3.40	45.85	4.24	NS
F	42.10	1.61	41.91	2.24	40.50	1.64			NS
T test	$P = 0.033$		$P < 0.001$		$P < 0.001$				
H-C3									
M	39.39	3.43	37.87	3.85	40.19	3.69	38.62	4.17	NS
F	32.67	2.42	32.80	2.73	36.62*	3.22			$P = 0.004$
T test	$P < 0.001$		$P < 0.001$		$P = 0.015$				
H⊥MP									
M	13.08	4.05	15.48	3.86	17.15*	4.71	20.75*	6.83	$P < 0.001$
F	7.83	5.31	12.41	6.07	15.18*	3.97			$P = 0.018$
T test	$P = 0.014$		$P = 0.050$		NS				
H⊥C3-Me									
M	5.14	3.91	4.99	4.29	6.67	4.05	9.74*	7.11	$P = 0.025$
F	-2.11	6.84	1.44	4.16	3.18	2.84			NS
T test	$P = 0.004$		$P = 0.014$		$P = 0.022$				

M, Male; F, female; NS, not significant.

T test, comparison between male and female subjects. ANOVA, comparison between the Si-Sn and the treatment groups.

*Statistically significant difference between the Si-Sn and the treatment groups.

coefficients. The variables entered into the model were H⊥MP, y-axis, N-ANS, neck size, H-C3, and Go-Me in men, and BMI, S-Ba, H-C3, S-Go, and Go-Me in women. R^2 values for these variables were 0.688 for men and

0.931 for women. In the discriminant analysis between the 4 groups (3 groups of women) for all cases, about 60% of the men and more than 85% of the women were correctly classified (Table V).

Fig 2. Craniofacial differences between the sexes in the Si-Sn group.

Fig 3. Craniofacial differences between the sexes in the Mo-OSAS group.

DISCUSSION

Although the RDI value of the women was significantly smaller than that of the men in the Mi-OSAS group and no woman was in the Se-OSAS group, the RDI value of the women was significantly greater than that of the men in the Mo-OSAS group. It was supposed that there might be sex differences in the progression of OSAS in a Taiwanese population.

There were no significant differences in mean ages among the groups for either sex or between >men and women for the Si-Sn, Mi-OSAS, Mo-OSAS groups. It is thought that there are no sex differences in age for the likelihood of having OSAS.

Obesity has been thought to be a primary cause of OSAS. Obesity might be related to OSAS because of excessive soft tissue in the upper airway. Our study also

Fig 4. Craniofacial differences between the Si-Sn and Se-OSAS groups in men.

Fig 5. Craniofacial differences between the Si-Sn and Mo-OSAS groups in women.

demonstrated that BMI and neck size statistically significantly increased with the severity of OSAS in both sexes. Male and female subjects differed in that the men in the Mi-OSAS group had a larger neck size. Ryan and Love³⁴ showed that obese patients with large necks tend to have a more easily collapsible velopharynx during wakefulness. The airway has a tendency to collapse from negative pressure associ-

ated with inspiration and airflow. The muscle tone of the palate, pharynx, and tongue help to balance the patency. Mass loading on the airway can produce changes in the airway configuration and its function. Cervical fat can produce a gravitational loading effect on the airway, especially when patients are supine. Obesity, through fat deposits around the upper airway in the neck, might narrow the pharynx and alter its

Table IV. Stepwise multiple regression analysis

Variable	Regression coefficient	P value
Men		
Constant	-114.638	0.114
H⊥MP	1.906	<0.001
Y-axis	1.671	0.007
N-ANS	-2.580	0.002
Neck size	3.268	0.022
H-C3	-1.507	0.024
Go-Me	0.957	0.090
	R = 0.688, R ² = 0.473, adjusted R ² = 0.418	
Women		
Constant	0.586	0.985
BMI	0.289	0.490
S-Ba	-0.420	0.602
H-C3	3.441	<0.001
S-Go	-1.853	<0.001
Go-Me	0.632	0.166
	R = 0.931, R ² = 0.866, adjusted R ² = 0.832	

Table V. Discriminant analysis (data are numbers of patients)

<i>Original group classification</i>	<i>n</i>	<i>Discriminant analysis classification (%)</i>			
		<i>Si-Sn</i>	<i>Mi-OSAS</i>	<i>Mo-OSAS</i>	<i>Se-OSAS</i>
Men					
Si-Sn	14	11 (78.6)	3 (21.4)	0 (0)	0 (0)
Mi-OSAS	29	6 (20.7)	15 (51.7)	5 (17.3)	3 (10.3)
Mo-OSAS	20	1 (5.0)	4 (25.0)	11 (55.0)	3 (15.0)
Se-OSAS	13	0 (0)	1 (7.7)	2 (15.4)	10 (76.9)
Women					
Si-Sn	9	7 (77.8)	2 (22.2)	0 (0)	
Mi-OSAS	14	2 (14.3)	12 (85.7)	0 (0)	
Mo-OSAS	10	0 (0)	0 (0)	10 (100)	

shape and mechanical properties, predisposing patients to sleep-related obstruction. Our results indicated that large BMI and neck size, especially in men, are risk factors associated with OSAS severity.

Certain forms of craniofacial anatomic defects, including inferior displacement of the hyoid bone, larger gonial angle, smaller anterior cranial base, altered anterior and posterior facial heights, and mandibular deficiency, have been suggested as predisposing factors for upper airway obstruction during sleep.^{28,35-39} It was shown that the hyoid bone positions relative to the mandible and the third vertebrae were different between men and women in the Si-Sn group. The distances from the hyoid bone to the third vertebrae and to the mandible in men were both statistically significantly greater (anteriorly and inferiorly) than those in women. Although

both female and male OSAS subjects had an inferiorly positioned hyoid bone compared with Si-Sn subjects, the changes of the hyoid bone positions as OSAS becomes severe were different between men and women. The position of the hyoid bone becomes more inferior as the condition becomes more severe, from Si-Sn to Se-OSAS, especially in men. In female patients, the position of the hyoid bone becomes more anterior as the OSAS condition becomes more severe.

The lingual musculature plays a strategic role in maintaining upper airway patency and is, moreover, anchored to the hyoid bone.^{40,41} An inferiorly positioned hyoid bone can be due to macroglossia, diffuse fat depositions, or relaxation of the lingual musculature. These conditions might cause the mandibular opening, making the gonial angle increase and altering anteroposterior facial height ratios. Therefore, an inferiorly positioned hyoid bone can impair upper airway patency because of involvement of the lingual musculature.

In addition to an inferiorly positioned hyoid bone, greater lower facial height was also related to an overall increase in OSAS severity in men, whereas larger SN to FH angle, smaller posterior facial height, and anteriorly positioned hyoid bone were related to an overall increase in OSAS severity in women. Based on results of the regression analysis, the following anthropometric and cephalometric characteristics are most likely to be expected in patients with severe OSAS: increased neck size and inferiorly positioned hyoid bone in both sexes, larger y-axis in men, and smaller posterior facial height and anteriorly positioned hyoid bone in women. From superimposition of the profiles of the Si-Sn and OSAS groups, it is clear that the major differences between these groups were in the anterior lower portion in men (inferiorly positioned chin and hyoid bone) and in the posterior portion in women (smaller posterior facial height). A larger y-axis implies more downward mandibular growth and is related to greater lower facial height. A smaller posterior facial height implies mandibular ramus deficiency and is related to a larger gonial angle and altered anterior and posterior facial heights.

Table IV shows that H-C3 (the distance from the third vertebra to the hyoid bone) had a negative correlation with the RDI in men and a positive correlation with the RDI in women. Previous studies showed that, although the hyoid bone position is associated with head posture, there is a regular pattern of downward and slightly anterior descent of the hyoid throughout the growth period.^{42,43} The role of the hyoid bone in the evolution of OSAS might differ between the

sexes. Further investigation in this area could help to clarify these issues.

CONCLUSIONS

There are obvious sex differences in the craniofacial skeletal characteristics that contribute to OSAS severity and, to evaluate OSAS severity, different anthropometric and cephalometric measurements should be used for men and women.

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