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ORIGINAL ARTICLE

Physical predictors for moderate to severe obstructive sleep apnea in snoring patients

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Abstract
Purpose This study aimed to identify physical findings that may predict the presence of moderate to severe obstructive sleep apnea (OSA) in snoring patients.
Methods A total of 283 subjects (165 males and 118 females) were recruited, including 217 OSA patients and 66 patients with apnea–hypopnea index (AHI)<5 as a control group, diagnosed by level-1 polysomnography. Baseline data of patients including age, sex, weight, height, body mass index (BMI), neck circumference (NC), waist circumference (WC), neck-to-height ratio (NHtR), and waist-to-height ratio (WHtR) were recorded. Other physical parameters such as chin length (Chin1), thyromental distance, hyomental distance, cricomental distance, cricomental space (CMS), Friedman tongue position (FTP), and tonsils size were recorded by a single investigator who was blinded to the PSG results.
Results The findings that were statistically different between the control group and moderate to severe OSA (AHI≥15) included sex, BMI, NC, NHtR, WC, WHtR, Chin1, CM, and CMS ($p<0.05$). However, logistic regression analysis showed that only male gender and WHtR≥ 0.55 were the independent predictors for AHI≥15 with adjusted odds ratios of 6.6 and 3.1, respectively.
Conclusion Among snoring patients seeking medical consultation, male gender and WHtR of≥0.55 were good predictors for moderate to severe OSA. No single head and neck finding reliably predicted this condition. In a situation with limited facilities, these data along with medical history may be helpful for prioritizing patients in order to achieve the optimal use of sleep investigation and treatment.

Keywords Obstructive sleep apnea · Sleep disordered breathing · Physical parameter · Predictor · Snoring · Thai

Introduction

Obstructive sleep apnea (OSA) is a common disorder found in approximately 24 and 9 % of middle-aged male and female subject in a large community-based study [1] and may be as high as one third of subjects presenting to the primary care clinics [2]. Nevertheless, up to 93 % of females and 82 % of males with moderate to severe OSA remain undiagnosed [3], which lead to increasing risks of several health consequences such as impaired quality of life [4], hypertension [5], and cardiovascular diseases [6]. Although polysomnography (PSG) performed in a sleep laboratory remains the current gold standard for diagnosis, its widespread use is limited by its high cost, labor intensity, and difficulty of access, particularly for several developing countries. Availability of a practical screening tool to predict OSA may be an interesting strategy to guide for optimum use of the overnight PSG.

Several studies have reported a number of important anthropometric risk factors for OSA such as male gender [7–11], obesity [9, 12–17], large neck circumference [8, 9, 13, 16–19], waist circumference [8, 13, 18], hypertrophic tonsils [12, 15, 20, 21], high modified Mallampati grade [12, 14, 16, 21, 22], narrowing of palate or oropharyngeal walls [20, 21], mandibular retrognathia [15], and small crico-mental space [23]. The interaction among these factors is believed to have an impact on pharyngeal lumen during sleep, leading to a more negative intraluminal pressure and narrowing of the airway, which is an important mechanism

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in the pathogenesis of OSA. However, there were considerable variations in the reports of these findings which may be due to differences in study designs, populations, and methods used to describe or quantify the abnormalities [8, 9, 12–18, 20, 21, 23, 24]. In addition, most of these studies were done in patients from the West and did not focus on the severity of OSA. Therefore, their usefulness for application in different populations, particularly for Asians, remains a question.

Since patients with moderate to severe OSA are likely to have more serious health consequences [25–28] and need a treatment approach different from simple snorers and patients with mild OSA [29–31], those who are at high risks for this condition should be diagnosed early and treated in a more expedited fashion. Given the limited medical facilities in several regions, including developing countries, determining the priority of patients suitable for objective investigation and treatment in a sleep clinic should be reconsidered and expeditiously executed. The objective of this study was, therefore, to identify physical findings of snoring patients that may predict the risks of moderate to severe OSA, which is helpful in this decision. Our study had recruited a relatively large number of Thai patients who were representatives of a least several Asian populations who have comparable anthropometric structures.

Materials and methods

This cross-sectional study was conducted at Siriraj Hospital between August 2011 and December 2012 after an approval from the Siriraj Institutional Review Board. All participants were recruited with consent forms after explanation of the procedures.

Control subjects

Sixty-six consecutive patients aged>18 years old who had apnea–hypopnea index (AHI)<5 diagnosed by gold standard PSG (level 1—sleep study) were recruited from Siriraj snoring clinic as a control group. Pregnant women or patients who had unstable medical co-morbidities such as active cardiopulmonary diseases, renal failure, or active thyroid disorders were not included in the investigation. All patients underwent a standard overnight technician-attended PSG (Compumedics Somte, Profusion III software, Victoria, Australia), which recorded electroencephalogram, electro-oculogram, electromyogram, electrocardiogram, nasal airflow measured by both nasal pressure transducer and thermistor, respiratory effort measured by thoracic and abdominal movement, oxygen saturation, and snoring sound recorded by a microphone. PSG tracings were scored manually by certified sleep technologists and reviewed by a board-certified sleep specialist who was unaware of the patients' information at the time of study. The definitions of PSG parameters followed the recommended criteria in the Manual of American Academy of Sleep Medicine (AASM) for the Scoring of Sleep and Associated Events 2007 [32]. The hypopnea was defined if there was a reduction of airflow measured by nasal pressure transducer≥30 % that lasted≥10 s along with≥4 % oxygen desaturation from the pre-event baseline. The exclusion criteria were patients who had total sleep time<2 h or did not have REM sleep in the sleep study.

Subjects with OSA

Two hundred seventeen consecutive patients with OSA, aged≥18 years old, who had a diagnosis confirmed by the gold standard full PSG (AHI≥5) were recruited from Siriraj snoring clinic. The patients were further classified by their diseases' severity into groups with mild OSA (AHI=5 to 14.99) and moderate to severe OSA (AHI≥15). The inclusion and exclusion criteria were similar to those of the control group. Physical examinations of all subjects were performed in a standardized way, as described in the following sections, by one otolaryngologist who was blinded to the PSG results similar to the control group.

Physical examination parameters

Demographic data including age, sex, weight (in kilograms), height (in meters), neck circumference (NC), and waist circumference (WC) of the patients were routinely recorded by a trained nurse assistant in the sleep clinic. A training session for a standardized technique of these measurements was held before study commencement. Body weight and height were recorded while patients were wearing light clothes and no shoes. Body mass index (BMI) was then calculated by the formula of weight (kg) divided by height^2 (m^2). The BMI was graded as non-obese (< 30 kg/m^2), obese (30–34.99 kg/m^2), and morbidly obese (≥ 35 kg/m^2). NC was measured in centimeters (cm) with a cord tape at the level of the cricothyroid membrane while all subjects were in the upright position. WC was measured in centimeters at the level of the umbilicus while subjects were standing at the end of expiration. The neck-to-height ratio (NHtR) and waist-to-height ratio (WHtR) were then calculated with the formula of NC (cm)/height (cm) and WC (cm)/height (cm), respectively.

Head and neck measurements were performed while patients were sitting upright with natural head position in a straight-backed chair at the end of the expiration phase without swallowing. Natural head posture was obtained by asking the patients to look straight ahead towards the wall of the examining room while the horizontal Frankfort line was parallel to the floor. To assess the mandible, a vertical line was dropped from the vermilion border of the lower lip. If the pogonion was more than 5 mm behind this line, mandibular retrognathia was then recorded. Chin lengths were measured from the lowest point of the chin to the lower vermilion border (chin1) and oral commissure (chin2) in the midline while patients were closing their mouth lightly. Thyromental distance (TMD), hyomental distance (HMD), and cricomental distance (CMD) were measured in centimeters with a standard ruler from the mental prominence to thyroid notch, hyoid bone, and cricoid cartilage, respectively (Fig. 1). Cricomental space (CMS) was measured as a perpendicular distance from the skin of the neck to the line of CMD as described in the study of Tsai. [23] We defined a narrowing of CMS if it was < 1 cm. All of these measurements were performed by a single investigator and were done twice in 40 patients on separate occasions, approximately 2–4 weeks apart, to test the intra-observer reliability.

The Friedman tongue position (FTP) or a modification of Mallampati's classification was assessed based on the visualization of oropharynx while the patients were opening their mouths widely without protrusion of the tongue as described in the study of Friedman [12]. The following FTP criteria were used: grade 1: tonsils, pillars, and soft palate were clearly visible; grade 2: the uvula, pillars, and upper pole of tonsils were visible; grade 3: only part of the soft palate was visible (the tonsils, pillars, and base of the uvula could not be seen); and grade 4: only the hard palate was visible.

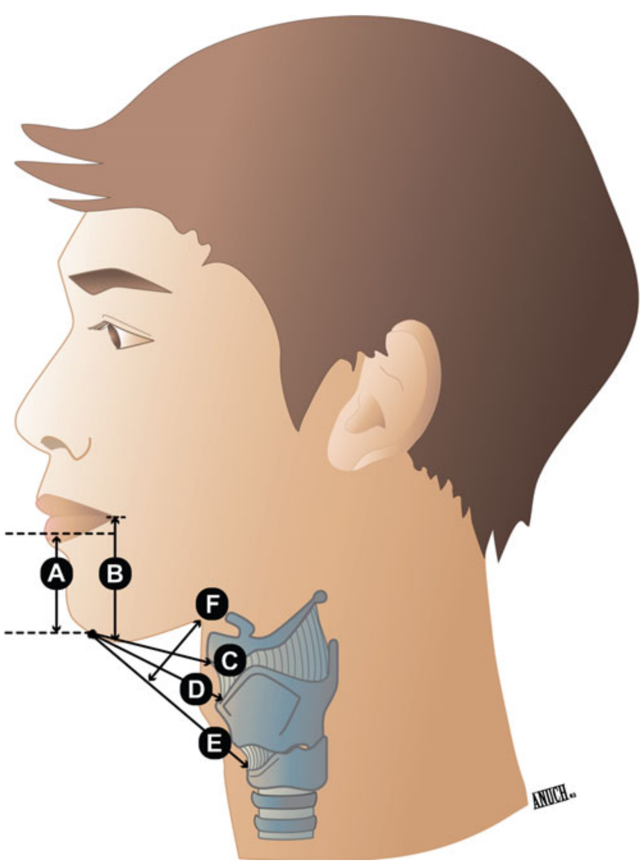

Fig. 1 Landmarks of head and neck measurement. *A* chin1 (distance from the lowest point of the chin to the lower vermilion border), *B* chin2 (distance from the lowest point of the chin to the oral commissure), *C* hyomental distance, *D* thyromental distance, *E* cricomental distance, *F* cricomental space

The grading of tonsil sizes was similar to those described in the study of Zanato [14] as follows: grade 0: the patient had had a tonsillectomy done; grade 1: tonsils were in the tonsillar fossa, barely seen behind the anterior pillars; grade 2: visible tonsil behind the anterior pillars occupied one fourth to half of the way to the midline of the oropharynx; grade 3: tonsils occupied more than half to three fourths of the way to the midline of the oropharynx; and grade 4: tonsils occupied more than three fourths of the way to the midline of the oropharynx, almost obstructing the airway (these are usually known as "kissing" tonsils).

Statistical analysis

The quantitative data were presented in mean ± standard deviations (SD). The qualitative data were calculated with Pearson's chi-square test. The reliability of repeated measurements was described by intra-class correlation coefficients (ICC). For comparison of means among different groups, we used either one-way analysis of variance (ANOVA) or Welch test depending on the homogeneity of variances and post hoc analysis with Hochberg or Games–Howell's test. Chi-square tests were used to compare dichotomous variables. Logistic regression analyses were performed between groups classified by AHI as dependent variables and other clinical parameters as independent variables. Cutoff points of each variable were selected from literature or from receiver operating characteristics (ROC) curve. The computer program used for calculation in this study was IBM SPSS version 18.0 (New York, NY, USA). Significant level was accepted at $p<0.05$ in two-tailed tests.

Results

A total of 283 subjects (165 males and 118 females) were recruited, including 217 OSA patients and 66 patients with AHI<5 as a control group. The demographic data of all patients are shown in Table 1. The reliability of repeated measurements was excellent, with ICC ranging from 0.90 to 0.92. The physical findings of all patients both in quantitative and qualitative measurements are presented in Table 2.

Physical findings among different OSDB severities

From ANOVA (Tables 1 and 2), the physical parameters that were statistically different among groups of patients included BMI, NC, NHtR, WC, WHtR, Chin1, CM, and CMS

Table 1 Demographic data of subjects

Groups	Control (N=66)	Mild OSA (N=71)	Moderate to severe OSA (N=146)	P-values
Male (N)	24	34	107	< 0.001[a]
Female (N)	42	37	39	
Premenopausal	21	13	14	0.308
Postmenopausal	21	24	25	
Age (year)	46.4±12.6	50.4±10.2	48.9±11.7	0.133
Height (cm)	162.1±8.9	161.8±8.9	165.6±8.6	0.002[a]
Weight (kg)	67.0 ±18.2	69.3±11.2	80.3±14.0	< 0.001[a]
BMI (m/kg^2)	25.3±5.2	26.5±4.0	29.3±4.9	< 0.001[b]
Total sleep time (min)	378.7±77.7	368.7±75.7	276.4±139.7	< 0.001[a]
Stage N1 (%)	16.3±12.8	16.6±10.6	30.4±18.0	< 0.001[a]
Stage N2 (%)	50.0±9.8	49.6±10.0	46.8±14.0	0.118
Stage N3 (%)	14.9±8.8	15.2±9.9	10.2±10.5	< 0.001[a]
Stage R (%)	17.4±7.1	17.6±6.8	12.2±8.6	< 0.001[a]
AHI	1.9±1.6	9.1±2.7	46.6±25.3	< 0.001[b]
AHI in NREM	1.4±1.4	7.3±3.1	40.3±30.6	< 0.001[b]
AHI in REM	2.4±1.8	10.9±2.2	52.9±23.3	< 0.001[b]
Mean O_2 (%)	96.2±1.6	95.4±1.4	91.9±5.0	< 0.001[a]
Minimal O_2 (%)	86.1±16.7	83.1±5.4	70.1±17.6	< 0.001[b]
ODI (4 %)	1.8±2.2	9.3±3.4	47.2±6.3	< 0.001[b]
Arousal index	24.0±11.4	29.2±13.2	45.9±22.2	< 0.001[a]

OSA obstructive sleep apnea, *BMI* body mass index, *AHI* apnea–hypopnea index, *Minimal O_2* minimal oxygen saturation during sleep, *ODI* oxygen desaturation index

[a] The statistical significance of difference was found between control and moderate to severe OSA

[b] The statistical significance of difference was found among all groups

($p<0.05$). In post hoc analysis, most of these differences were found between the control group (AHI <5) and patients with moderate to severe OSA (AHI≥15). No significant difference was found between the control group and mild OSA, except for BMI, NC, NHtR, and WHtR ($p<0.05$). Pearson's chi-square tests demonstrated that male gender was a significant parameter that differed among groups of patients. Nevertheless, there was no statistically significant difference between pre- and postmenopausal females among patients with different severities of OSA as shown in Table 1.

In order to predict moderate to severe OSA more clearly from physical findings, binary logistic regression analysis was performed between the control group (AHI<5) and the moderate to severe OSA group (AHI≥15) as shown in Table 3. Variables included in multivariate analysis were selected from those with p-values<0.2 from univariate analysis. Cutoff points of BMI (30 kg/m^2) and NC (40 cm) were selected from literature [31, 33]. Other variables were selected from ROC curves with area under curve ranging from 0.59 to 0.88. For example, the cutoff point 0.55 of WHtR was selected from an optimal point in the ROC curve at sensitivity of 73 % and specificity of 69 %. After control for other factors in the analysis, male gender and WHtR≥0.55 were the only significant predictors for moderate to severe OSA with adjusted odds ratios of 6.6 and 3.1, respectively. We did not include mild OSA group in the last stepwise analysis since it was considered as a disease and most of its parameters did not have statistically significant differences from the control.

Discussion

Although several studies had reported physical risk factors of OSA, most of them were done in Western patients who have different features from Asians, and the results were often inconsistent. In addition, their investigations did not focus on patients with moderate to severe OSA who were at greater risks of morbidity or mortality and potentially get more benefits from early treatment, particularly with CPAP, than mild OSA [25–31]. This study, therefore, had demonstrated different points of view from previous reports.

Our results showed that the physical parameters that were statistically different among groups of patients included sex, BMI, NC, NHtR, WC, WHtR, Chin1, CM, and CMS ($p<0.05$). Most of these differences were found between the control group (AHI <5) and patients with moderate to severe OSA (AHI≥15), not with mild OSA, except for BMI,

Table 2 Physical findings in all subjects

Groups		Control (*N*=66)	Mild OSA (*N*=71)	Moderate to severe OSA (*N*=146)	*P*-values
Sex	Male (%)	24 (14.5)	34 (20.6)	107 (64.8)	< 0.001[b]
	Female (%)	42 (35.6)	37 (31.4)	39 (33.1)	
NC (cm)		35.1 ± 3.8	36.8 ± 2.9	39.3 ± 4.2	< 0.001[c]
NHtR		0.22 ± 0.02	0.23 ± 0.02	0.24 ± 0.02	< 0.001[c]
WC (cm)		86.4 ± 12.8	90.5 ± 8.6	98.7 ± 10.6	< 0.001[b]
WHtR		0.53 ± 0.07	0.56 ± 0.06	0.60 ± 0.07	< 0.001[c]
Chin1 (cm)		3.5 ± 0.4	3.5 ± 0.4	3.7 ± 0.4	0.017[a]
Chin2 (cm)		4.2 ± 0.8	4.1 ± 0.4	4.3 ± 0.4	0.089
HM (cm)		5.0 ± 1.0	5.0 ± 0.9	5.0 ± 0.9	0.354
TM (cm)		6.1 ± 1.0	6.0 ± 1.0	6.3 ± 1.0	0.103
CM (cm)		8.3 ± 1.2	8.5 ± 1.3	8.9 ± 1.2	0.006[a]
CMS (cm)		1.1 ± 0.5	1.0 ± 0.4	0.8 ± 0.5	0.002[a]
FTP	1 and 2	8 (44.4)	2 (11.1)	8 (44.4)	0.065
	3 and 4	57 (21.8)	69 (26.3)	136 (51.9)	
Tonsils grade	1 and 2	59 (23.8)	63 (25.4)	126 (50.8)	0.292
	3 and 4	3 (12.5)	5 (20.8)	16 (66.7)	

The quantitative data are presented as mean±standard deviation (S.D.), but the qualitative data are presented as number (%)

OSA obstructive sleep apnea, *BMI* body mass index, *NC* neck circumference, *NHtR* neck-to-height ratio, *WC* waist circumference, *WHtR* waist-to-height ratio, *FTP* Friedman tongue position, *Chin1* chin midline length, *Chin2* chin to oral commissure, *HM* hyomental distance, *TM* thyromental distance, *CM* cricomental distance, *CMS* cricomental space

[a] Statistically significant difference was found only between control and moderate-to-severe OSA

[b] Statistically significant differences were found between control and moderate-to-severe OSA as well as between mild OSA and moderate-to-severe OSA

[c] Statistically significant difference was found among all groups

NC, NHtR, and WHtR. The significant differences, particularly in BMI [9, 12–17, 34, 35], WC [8, 13, 18, 35], NC [8, 9, 13, 16–19, 35], NHtR [10], and CMS [23], between control group and OSA in this study were in accordance with several of the previous reports. Nevertheless, our data did not show significant differences of FTP between OSA patients and controls, which confirmed the report of Erdamar [15] and Hukins [36] but in contrast to the reports of Friedman [12], Yagi [21], Zonato [14], Liistro [22], and Barcelo et al. [37]. In addition, the insignificant difference of HM and TM among groups of patients had confirmed the reports of Friedman et al. [12]. Although the grading of tonsil size was reported as a risk factor for OSA in several studies [12, 15, 20, 21, 37], its statistically significant difference between the control and moderate to severe OSA group was not found in this study, which was in accordance with the reports of Dreher et al. [24]. This negative finding was likely due to the use of AHI cutoff point at 15 instead of 5 since we had a different focusing point from others. In addition, it may be possible that an enormous tonsil size (grade 3 or 4) is uncommon among adults with OSDB, particularly in our study where this feature presented in only 24 out of 283 patients or less than 10 %, which may be insufficient for a statistical power.

After adjusting for other contributing factors with logistic regression analysis, we had found that only male gender and WHtR≥0.55 were significantly associated with moderate to severe OSA with adjusted odds ratios of 6.6 and 3.1, respectively. The results from this multivariate analysis demonstrated that no single head and neck parameters of patients reliably predicted moderate to severe OSA, which was in accordance with the study of Dreher et al. [24]. The influence of gender on the severity of OSA, as shown in this study, was in agreement with the literature [7–11, 34, 38, 39] and supported the hypothesis that the pathophysiology of OSA between men and women is different, which is probably due to differences in body fat distribution [40] and upper airway functions [11, 41]. Unfortunately, our data did not show that postmenopausal status was an independent factor for moderate to severe OSA, and there were only ten females in this group who had been treated with hormornal replacement, which was inadequate for conclusion. Nonetheless, we believed that menopausal status is important and that additional research should be required for emphasizing this issue.

In addition to the influence of gender, our results had pointed out another interesting parameter, WHtR, which may become more important than BMI in predicting

Table 3 Logistic regression analysis of factors affecting moderate to severe OSA compared to control

Groups		Control[a] (*N*=66)	Moderate to severe OSA[a] (*N*=146)	Univariate		Multivariate	
				Crude OR (95 % CI)	*P*-values[b]	Adjusted OR (95 % CI)	*P*-values[c]
Sex	Male	24 (14.5)	107 (64.8)	4.8 (2.6–8.9)	< 0.001	6.6 (2.3–19.3)	< 0.001
	Female	42 (35.6)	39 (33.1)				
BMI (kg/m^2)	<30	59 (29.2)	87 (43.1)	5.7 (2.4–13.4)	< 0.001	1.7 (0.5–5.3)	0.377
	≥30	7 (8.6)	59 (72.8)				
NC	<40	55 (29.1)	79 (41.8)	5.2 (2.4–11.3)	< 0.001	0.6 (0.2–2.1)	0.464
	≥40	9 (10.0)	67 (74.4)				
NHtR	<0.23	50 (34.5)	54 (37.2)	6.1 (3.1–12.0)	< 0.01	1.9 (0.7–5.1)	0.225
	≥0.23	14 (10.4)	92 (68.7)				
WC	<90	41 (39.8)	30 (29.1)	6.9 (3.6–13.2)	< 0.001	1.7 (0.6–4.8)	0.293
	≥90	23 (13.2)	116 (66.7)				
WHtR	<0.55	44 (37.9)	39 (33.6)	6.0 (3.2–11.5)	< 0.001	3.1 (1.1–9.7)	0.046
	≥0.55	20 (12.4)	107 (66.5)				
FTP	1 and 2	8 (44.4)	8 (44.4)	2.4 (0.9–6.7)	0.097	1.3 (0.3–4.7)	0.714
	3 and 4	57 (21.8)	136 (51.9)				
Tonsils grade	1 and 2	59 (23.8)	126 (50.8)	2.5 (0.7–8.9)	0.158	1.9 (0.4–9.5)	0.442
	3 and 4	3 (12.5)	16 (66.7)				
Chin1 (cm)	≤3.5	41 (27.2)	67 (44.4)	1.9 (1.1–3.5)	0.030	0.9 (0.4–2.2)	0.848
	>3.5	25 (18.9)	79 (59.8)				
Chin2 (cm)	≤4.5	57 (23.8)	117 (49.0)	1.6 (0.7–3.5)	0.276	1.4 (0.4–5.0)	0.579
	>4.5	9 (20.5)	29 (65.9)				
TM (cm)	<6	24 (24.7)	42 (43.3)	1.4 (0.8–2.6)	0.270	0.6 (0.2–1.6)	0.329
	≥6	42 (22.6)	104 (55.9)				
CM (cm)	<9	42 (27.6)	68 (44.7)	2.0 (1.1–3.6)	0.022	0.9 (0.3–2.4)	0.838
	≥9	24 (18.3)	78 (51.6)				
CMS (cm)	>1	35 (31.8)	43 (39.1)	2.7 (1.5–4.8)	0.001	1.9 (0.9–4.2)	0.118
	≤1	31 (18.1)	101 (59.1)				

OR odds ratio, *CI* confidence interval, *OSA* obstructive sleep apnea, *BMI* body mass index, *NC* neck circumference, *NHtR* neck-to-height ratio, *WC* waist circumference, *WHtR* waist-to-height ratio, *FTP* Friedman tongue position, *Chin1* chin midline length, *Chin2* chin to oral commissure, *TM* thyromental distance, *CM* cricomental distance, *CMS* cricomental space

[a] Data are presented as number of subjects (%)

[b] *P*-values representing the significance of adjusted odds ratio from univariate analysis

[c] *P*-values representing the significance of adjusted odds ratio from multivariate analysis

moderate to severe OSA. The advantage of WHtR over BMI is that it indicates central obesity or visceral fat, while BMI neither distinguishes between muscle and fat accumulation nor represents the distribution of fat. The WHtR has also been supported by several studies including meta-analyses as a better tool for predicting risks of mortality in cardiovascular events and metabolic syndromes such as hypertension and diabetes mellitus [42–44]. When compared with another popular anthropometric parameter such as waist-to-hip ratio (WHR), WHtR seems to be a more reasonable tool since WHtR usually changes directly following WC compared with a constant height in adult, while WHR can change only little even though there is a significant change in body size due to a proportionate increase or decrease of both WC and hip circumference [42].

There were some potential limitations of this study. Firstly, the baseline characteristics among groups of patients were not perfectly matched since patients with more severe forms of OSA had a greater weight and BMI than controls. Nevertheless, this was not surprising since it is well known in clinical practice and we had already adjusted these potential confounders with logistic regression analysis. Secondly, some of other important head and neck parameters such as facial skeletal, dental occlusion, uvula or palatal length, tongue base, and laryngeal abnormalities may also contribute to OSA severity, but we did not include them in this study. Our reasons are that most of these parameters were relatively subjective and should have been better recorded by more sophisticated investigations such as lateral cephalometry, computerized tomography, or flexible sleep endoscopy rather than a simple examination by a sleep physician in the clinic. Therefore, including these parameters may not be suitable for our study which was aimed for a simple practice in sleep clinic. Nonetheless, we should not neglect the importance of head and neck examination since it remains useful in the treatment of OSA patients. Finally, our cutoff points of parameters such as 0.55 in WHtR may not be equal to those reported from the Western literature [45]. However, some authors had suggested the optimal cutoff points for WHtR to be somewhere between 0.5 to 0.6 and that their variations were possibly different among ethnic groups [42, 43]. Therefore, future research is required to determine whether similar results hold for predicting of OSA and whether our cutoff point is consistent across ethnic groups.

In conclusion, patients with more severe forms of OSA had significant differences in several physical findings compared with simple snorers. However, the only independent parameters of snoring patients which could predict moderate to severe OSA were male gender and WHtR>0.55. These meant that we should screen for both parameters and not rely on a single local physical finding to predict the severity of OSA. These data combined with medical history help us to prioritize patients for sleep investigation or initiating a treatment, particularly in a situation with limited medical facilities. However, it would be possible that our findings may apply for Thai subjects but not for other different populations. With an increasing body of evidences, we believe that a comprehensive systematic review or meta-analysis may be required to address these issues.

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

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