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Polysomnographic and Cephalometric Evaluation of Patients with Obstructive Sleep Apnea According to Obesity Level

Jung Hwan Jo[1],* | Ji Woon Park[1,2],* | Ji Hee Jang[1] | Jin Woo Chung[1,2]

[1]Department of Oral Medicine, Seoul National University Dental Hospital, Seoul , Korea
[2]Department of Oral Medicine and Oral Diagnosis, School of Dentistry and Dental Research Institute, Seoul National University, Seoul, Korea

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Correspondence to:
Jin Woo Chung
Department of Oral Medicine and Oral Diagnosis, School of Dentistry and Dental Research Institute, Seoul National University, 101 Daehak-ro, Jongno-gu, Seoul 03080, Korea
Tel: +82-2-2072-3021
Fax: +82-2-744-9135
E-mail: jwchung@snu.ac.kr
https://orcid.org/0000-0003-3738-3386
*These two authors contributed equally to this work.

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Purpose: This study aimed to evaluate polysomnographic and cephalometric characteristics of patients with OSA according to obesity level based on the World Health Organization (WHO) Asian-Pacific BMI criteria.

Methods: One hundred and thirty-one consecutive patients with obstructive sleep apnea (OSA) were evaluated using standard level 1 polysomnography and cephalometric analyses. The subjects were categorized into normal, overweight and obese groups according to the WHO Asian-Pacific BMI criteria. Respiratory indices and cephalometric parameters were compared among groups.

Results: The 131 patients consisted of 111 males and 20 females, with a mean age of 44.1±12.4 years. The mean value of BMI was 25.3±3.4 kg/m^2 for all subjects, 20.6±2.2 kg/m^2 for normal (n=27), 24.0±0.5 kg/m^2 for overweight (n=33) and 27.6±2.2 kg/m^2 for obese (n=71). The obese group had a significantly higher apnea-hypopnea index (AHI) and respiratory arousal index and lower oxygen saturation level than the normal group ($p<0.05$). Total AHI, mean oxygen saturation level and respiratory arousal index were significantly correlated with BMI ($p<0.001$). A longer soft palate and anterior position of the hyoid bone were significantly correlated with BMI level ($p \leq 0.05$).

Conclusions: Obese patients have a higher risk of compromised craniofacial skeletal features and soft tissue structures, and severe OSA than non-obese patients.

Keywords: Body mass index; Cephalometry; Obesity; Obstructive sleep apnea; Polysomnography

INTRODUCTION

Obstructive sleep apnea (OSA) is a common disorder and public health problem, characterized by loud snoring and frequent events of upper airway collapse while sleeping. The estimated prevalence of OSA has increased by about three times over the past two decades [1]. The major concern is that most individuals that have OSA have been underdiagnosed hence undertreated, resulting in an extensive range of health problems including cardiovascular disorders, increased risk of car accidents, metabolic disorders, cognitive impairment, depression, stroke and reduced quality of life, ultimately enhancing its socio-economic burden [2-4].

The pathogenesis of OSA is multifactorial and heterogeneous, and the most significant recognized risk factor for OSA is obesity. The prevalence of OSA in obese men and women is approximately 40%, and 70% of OSA patients [5,6]. A Large cohort epidemiologic study found that a 10% increase in weight increased the risk of moderate to severe OSA by six times and the apnea-hypopnea index (AHI) by

32% [7]. Obesity and increased body fat are known to reduce the size of the upper airway, and to increase the risk of collapse and obstruction [8].

Previous studies have reported the tendency of high risk of OSA in obese patients based on body mass index (BMI). Vgontzas et al. [9] reported that severe obese men (BMI≥32 kg/m^2) showed a 48% increased risk of sleep apnea. Leong et al. [10] revealed severe obese patients (BMI≥35 kg/m^2) had a significantly greater prevalence and severity of OSA. However, various cut-offs of BMI mainly used in studies to assess obesity in OSA patients in the Western population are not suitable to be accepted as reference data for Korean OSA patients because of the difference in criteria to group obesity and the effect of obesity on OSA in different ethnic groups. Besides the prevalence of nonobese OSA patients is known to be higher in Asians than in Caucasians [11]. Although there is controversy over the most appropriate BMI classification for the Asian population because of their physical structural difference from the Western population, World Health Organization (WHO) has recommended a distinct definition of obesity with specific categories for the Asian population [12].

Lateral cephalography is used to analyze alterations of the upper pharyngeal and oral airway in OSA patients. Low radiation dose, cost-effectiveness, and ease of analysis make lateral cephalograms a widely used radiographic tool to evaluate upper airway structures in OSA patients, despite being a two-dimensional technique [13,14]. However few studies have evaluated airway alterations in obese patients with OSA using lateral cephalography based on the WHO Asian-Pacific criteria for obesity.

Therefore, this study analyzed the polysomnographic and cephalometric characteristics of OSA patients according to obesity level based on the WHO Asian-Pacific BMI criteria.

MATERIALS AND METHODS

1. Subjects

One hundred and thirty-one consecutive adult patients (age≥20 years) who visited the sleep laboratory in Seoul National University Dental Hospital from July 2007 to April 2016 were evaluated. All patients underwent level I nocturnal polysomnography (PSG) and those who diagnosed with OSA (AHI≥5) were evaluated. Exclusion criteria were patients with central sleep apnea, previous history of major surgery or trauma in the face and neck region, severe craniofacial abnormality, medication intake for sleep disorders, pregnancy, or major cardiopulmonary disorders. This study was approved by the Institutional Review Board of Seoul National University Dental Hospital and informed consent was obtained from all individual participants included in the study (CRI 08027).

2. Polysomnographic Evaluation

All subject underwent a full-night multi-channel standard PSG using a standardized device (Alice 5; Respironics, Pittsburgh, PA, USA). All sleep parameters were scored based on the updated criteria by the American Academy of Sleep Medicine [15].

The Epworth Sleepiness Scale (ESS), an 8-item questionnaire, where a higher score means higher level of daytime sleepiness, was performed to evaluate subjective sleepiness [16]. BMI was determined as weight in kilograms and the square of height in meters (kg/m^2) by measuring body height and body weight prior to the overnight PSG. Neck circumference was measured at the midway of the neck in the upright position with a flexible ruler. Subjects were categorized into three groups according to the WHO classification of obesity for the Asian population: normal (BMI<23 kg/m^2), overweight (23 kg/m^2≤BMI<25 kg/m^2), and obese (BMI≥25 kg/m^2) [12].

3. Cephalometric Analyses

Standard lateral cephalogram were performed using Asahi CX-90 SP II (Asahi, Toshiba, Japan) and 10×12-inch FCR IP cassette (Fujifilm, Tokyo, Japan). Radiographs were obtained using a standardized technique, with the patient upright.

Digital images were assessed using V-ceph program (version 5.3; Osstem Inc., Seoul, Korea) for linear and angular measurements. The landmarks and measurements in the analysis are shown in Fig. 1 and all measurements used are descripted in Table 1 [17,18].

4. Statistical Analyses

Descriptive statistics were computed and values were described as mean (standard deviation). Differences in demographic characteristics and clinical variables including age, sex, BMI, neck circumference, ESS, and comorbidity among subgroups according to obesity were analyzed with one-way ANOVA and chi-square test. Polysomnographic variables including AHI, OSA severity group, oxygen saturation, total sleep time, sleep stage, sleep efficiency and arousal index along with cephalometric parameters among subgroups according to obesity were analyzed with one-way ANOVA and chi-square test. The correlation between clinical characteristics and polysomnographic indices and BMI were obtained from Pearson's correlation analysis

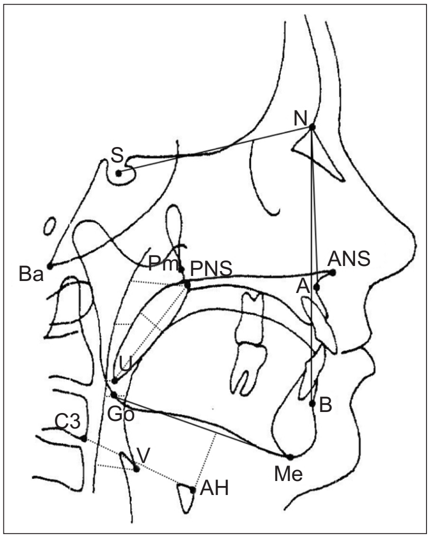

Fig. 1. Landmarks used in cephalometric analysis. S, sella; N, nasion; A, subspinale; B, supramentale; PNS, posterior nasal spine; U, tip of the uvula; AH, the most anterior and superior point of hyoid bone; Go, gonion; Me, menton; C3, the anterior border of the third vertebra; Ba, basion; V, vallecular.

IBM SPSS Statistics for Windows, Version 25.0 (IBM Co., Armonk, NY, USA) was used for statistical analysis. Statistical significance level was set at $p<0.05$.

RESULTS

1. Demographic and Clinical Features

A total 131 patients compromised 111 men and 20 women. Their mean age was 44.1±12.4 years and age ranged from 20 to 82 years. The mean value of BMI was 25.3±3.4 kg/m^2. The subjects were categorized into three groups according to obesity; normal (20.6±2.2 kg/m^2, n=27, 20.6%); overweight (24.0±0.5 kg/m^2, n=33, 25.2%); obese (27.6±2.2 kg/m^2, n=71, 54.2%).

Table 2 shows demographic and clinical differences among subgroups. Neck circumference in the obese group was 39.7±3.0 cm, and significantly longer than those of the other two groups (34.2±3.5 cm for normal, 37.1±2.6 cm for overweight, $p<0.001$). There were no significant differences in sex, age, ESS, comorbid hypertension and diabetes mellitus between subgroups.

2. Polysomnographic Assessment According to Obesity Groups

As shown in Table 3, the obese group showed significantly higher percentage of severe OSA patients (AHI≥30/h) than the other two groups ($p=0.007$). The obese group showed

Table 1. Linear and angular measurements used in cephalometric analysis

Measurement	Definition
SNA	Smaller angle which is formed by S, N and A point
ANB	Smaller angle which is formed by A point, N, and B point
PNS-U	The distance between PNS and U
SPT	Maximum width of soft palate which is perpendicular to PNS-U line
MPH	The perpendicular distance between AH and Go-Me line
AH-C3	The distance between AH and the third vertebra
Nasal airway space	The distance from the intersection of Ba-PNS and posterior pharyngeal wall to PNS
Superior oral airway space	The distance from the ventral surface of the soft palate to posterior pharyngeal wall, measured through a point midway between PNS and U along parallel to the line to Go-B plane
Middle oral airway space	The distance from U to posterior pharyngeal wall along parallel to the line to Go-B plane
Inferior oral airway space	The distance from the anterior to posterior pharyngeal wall along Go-B line
Hyoid airway space	The perpendicular distance from V to posterior pharyngeal wall

S, sella; N, nasion; A, subspinale; B, supramentale; PNS, posterior nasal spine; U, tip of the uvula; AH, the most anterior and superior point of hyoid bone; Go, gonion; Me, menton; C3, the anterior border of the third vertebra; Ba, basion; V, vallecula

Table 2. Demographic and clnical features of OSA patients according to obesity

Variable	Total (n=131)	Normal (n=27)	Overweight (n=33)	Obese (n=71)	p-value
Age[a], yr	44.1 (12.4)	43.4 (13.7)	44.2 (13.6)	44.3 (11.4)	0.954
Age>55 yr[b], %	18.3	18.5	18.2	18.3	0.999
Sex (male)[b], %	84.7	70.4	90.9	87.3	0.059
BMI[a], kg/m^2	25.3 (3.4)	20.6 (2.2)	24.0 (0.5)	27.6 (2.2)	<0.001*
Neck circumference[a], cm	37.8 (3.7)	34.2 (3.5)	37.1 (2.6)	39.7 (3.0)	<0.001*
ESS[a]	8.3 (4.5)	9.1 (4.8)	8.8 (4.3)	7.7 (4.1)	0.271
Hypertension[b], %	25.0	12.0	29.0	28.1	0.240
Diabetes mellitus[b], %	6.7	0.0	12.9	6.3	0.154

OSA, obstructive sleep apnea; BMI, body mass index; Normal, BMI<23 kg/m^2; Overweight, 23 kg/m^2≤BMI<25 kg/m^2; Obese, 25 kg/m^2≤BMI; ESS, epworth sleepiness scale.

Values are presented as mean (standard deviation) or %.

[a]Results were obtained from one-way ANOVA. [b]Results were obtained from chi-square test.

*Significant difference: p<0.05.

Table 3. Polysomnographic indices of OSA patients according to obesity

Variable	Total (n=131)	Normal (n=27) [1]	Overweight (n=33) [2]	Obese (n=71) [3]	p-value	Post-hoc : Tukey's test
Total AHI[a], /h	27.9 (21.7)	18.3 (13.2)	25.0 (19.5)	32.9 (26.5)	0.014*	[1]-[3]*
Supine AHI[a], /h	35.2 (26.7)	25.0 (19.2)	31.4 (25.1)	40.9 (28.5)	0.018*	[1]-[3]*
Non-supine AHI[a], /h	11.4 (20.6)	4.0 (7.5)	8.3 (15.1)	15.6 (24.8)	0.026*	[1]-[3]*
REM AHI[a], /h	34.6 (23.3)	25.4 (18.2)	32.7 (20.4)	39.0 (25.3)	0.029*	[1]-[3]*
NREM AHI[a], /h	26.3 (24.6)	17.2 (14.5)	24.0 (20.9)	30.8 (28.1)	0.039*	[1]-[3]*
Severe OSA group[b], %	40.4	11.1	33.3	45.1	0.007*	[1]-[2]*, [1]-[3]*, [2]-[3]*
Mean SpO_2[a], %	95.2 (1.9)	96.1 (1.5)	95.9 (1.4)	94.5 (2.0)	<0.001*	[1]-[3]*, [2]-[3]*
Lowest SpO_2[a], %	80.5 (9.7)	85.9 (5.3)	81.8 (7.2)	77.9 (11.0)	0.001*	[1]-[3]*
REM SpO_2[a], %	94.0 (8.8)	96.2 (1.5)	95.3 (1.8)	92.5 (11.6)	0.104	
NREM SpO_2[a], %	95.2 (2.0)	96.1 (1.4)	96.0 (1.4)	94.4 (2.1)	<0.001*	[1]-[3]*, [2]-[3]*
Time below 90% SpO_2[a], %	5.1 (8.9)	1.5 (2.6)	2.5 (4.0)	7.6 (11.1)	0.001*	[1]-[3]*, [2]-[3]*
Total sleep time[a], min	319.1 (62.9)	328.8 (74.2)	318.1 (45.2)	315.8 (65.8)	0.659	
Sleep efficiency[a], %	80.4 (11.8)	79.7 (11.6)	81.1 (11.8)	80.4 (12.1)	0.910	
Sleep latency[a], min	16.2 (16.5)	16.0 (13.9)	14.9 (15.5)	16.9 (18.0)	0.840	
REM latency[a], min	119.7 (59.0)	117.0 (64.3)	115.9 (66.1)	122.4 (53.9)	0.842	
Sleep stage I[a], %	28.2 (15.6)	26.7 (10.3)	27.2 (14.8)	29.2 (17.6)	0.712	
Sleep stage II[a], %	48.0 (14.4)	49.2 (10.4)	48.9 (13.5)	47.2 (16.1)	0.770	
Sleep stage III+IV[a], %	2.6 (5.4)	2.5 (4.0)	3.2 (4.6)	2.3 (6.1)	0.735	
REM sleep[a], %	16.8 (7.0)	17.7 (6.5)	17.2 (7.1)	16.3 (7.2)	0.619	
Time of supine position[a], %	72.4 (24.9)	75.9 (24.6)	77.4 (28.0)	68.7 (23.2)	0.181	
REM arousal index[a], /h	16.8 (14.6)	12.4 (13.2)	16.5 (12.2)	18.6 (15.8)	0.189	
NREM arousal index[a], /h	14.9 (16.8)	11.2 (14.8)	11.7 (10.7)	17.7 (19.2)	0.125	
Respiratory arousal index[a], /h	17.7 (17.8)	11.5 (11.0)	15.5 (13.5)	21.2 (20.7)	0.038*	[1]-[3]*
Total arousal index[a], /h	29.8 (16.2)	29.0 (13.8)	26.5 (12.4)	31.6 (18.3)	0.325	

OSA, obstructive sleep apnea; Normal, body mass index (BMI)<23 kg/m^2; Overweight, 23 kg/m^2≤BMI<25 kg/m^2; Obese, 25 kg/m^2≤BMI; AHI, apnea-hypopnea index; REM, rapid eye movement sleep; NREM, non-rapid eye movement sleep; OSA, obstructive sleep apnea; SpO_2, oxygen saturation.

Values are presented as mean (standard deviation) or %.

[a]Results were obtained from one-way ANOVA. [b]Results were obtained from chi-square test.

*Significant difference: p<0.05.

significantly higher respiratory disturbance indices including total AHI, supine AHI, non-supine AHI, rapid eye movement (REM) AHI, and non-rapid eye movement (NREM) AHI than the normal weight group (p<0.05). As for oxygen saturation levels, the obese group showed significantly lower mean oxygen saturation (SpO_2), NREM SpO_2, and higher

Table 4. Cephalometric parameters of OSA patients according to obesity

Variable	Total (n=131)	Normal (n=27) [1]	Overweight (n=33) [2]	Obese (n=71) [3]	p-value	Post-hoc : Tukey's test
SNA, °	79.2 (5.0)	78.2 (5.0)	80.8 (4.7)	78.9 (5.1)	0.100	
ANB, °	0.3 (3.3)	1.2 (2.8)	0.9 (2.8)	−0.3 (3.2)	0.047*	[1]-[3]*
MPH, mm	20.1 (6.2)	18.6 (6.3)	20.9 (5.4)	20.3 (6.4)	0.328	
AH-C3, mm	43.1 (5.6)	39.3 (5.4)	42.9 (4.7)	44.5(5.5)	<0.001*	[1]-[2]*, [1]-[3]*
SPT, mm	12.0 (2.7)	11.8 (3.4)	11.5 (2.0)	12.2 (2.7)	0.415	
PNS-U, mm	40.8 (5.6)	39.3 (5.4)	40.2 (6.2)	41.7 (5.3)	0.135	
NL/PNS-U, mm	82.7 (33.1)	86.7 (29.1)	75.3 (42.0)	84.5 (29.8)	0.331	
Nasal airway space, mm	25.5 (3.6)	24.8 (3.0)	25.7 (3.2)	25.7 (4.1)	0.530	
Superior oral airway space, mm	11.7 (3.5)	11.4 (3.7)	12.0 (3.1)	11.6 (3.7)	0.794	
Middle oral airway space, mm	9.1 (3.4)	8.3 (2.8)	9.6 (3.2)	9.5 (3.6)	0.212	
Inferior oral airway space, mm	11.0 (3.8)	10.0 (2.3)	11.2 (3.4)	11.6 (4.1)	0.109	
Hyoid airway space, mm	18.0 (5.6)	16.0 (4.4)	18.8 (6.0)	18.8 (6.0)	0.100	

OSA, obstructive sleep apnea; Normal, body mass index (BMI)<23 kg/m^2; Overweight, 23 kg/m^2≤BMI<25 kg/m^2; Obese, 25 kg/m^2≤BMI; REM, rapid eye movement sleep; SNA, smaller angle formed by sella, nasion (N), and A point; ANB, smaller angle formed by A point, N, and B point; MPH, the perpendicular distance from AH to Go-Me line; AH-C3, the distance from AH to the third vertebra; SPT, maximum width of soft palate which is perpendicular to PNS-U line; PNS-U, the distance from PNS to U; NL/PNS-U, smaller angle between ANS-Pm line and PNS-U line.

Values are presented as mean (standard deviation).

Results were obtained from one-way ANOVA.

*Significant difference: p<0.05.

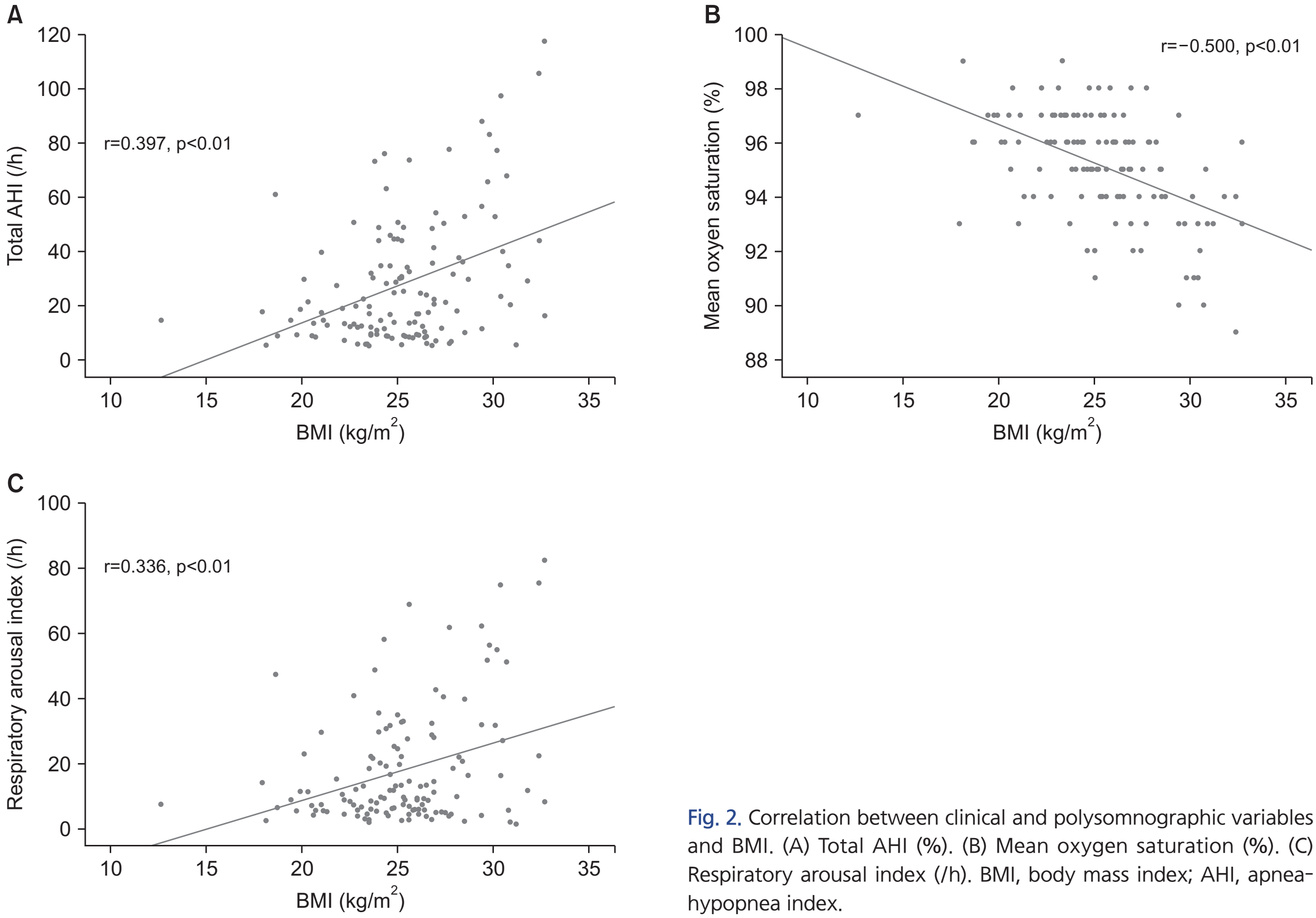

Fig. 2. Correlation between clinical and polysomnographic variables and BMI. (A) Total AHI (%). (B) Mean oxygen saturation (%). (C) Respiratory arousal index (/h). BMI, body mass index; AHI, apnea-hypopnea index.

percentage of time below 90% SpO_2 than the other two groups, and showed a significantly lower lowest SpO_2 than the normal group ($p<0.01$). The obese group showed significantly higher respiratory arousal index than the normal weight group ($p<0.05$). However, total sleep time, the percentage of sleep stage, percentage of REM sleep, percentage of supine position, sleep efficiency, sleep latency, REM latency, REM and NREM arousal index, and total arousal index among subgroups did not show significant differences.

3. Cephalometric Analysis According to Obesity Groups

Table 4 shows differences in eleven linear and angular measurements of cephalometric analysis among subgroups. The AH-C3 was significantly shorter in the normal group than the other obese and overweight groups ($p<0.01$). Obese groups had a significantly narrower ANB than the normal group ($p<0.05$). The obese group showed a longer MPH distance and narrower nasal airway space and superior oral airway space than the other two groups, but the differences did not show statistical significance.

4. Correlations between Clinical and Polysomnographic Parameters and BMI

Fig. 2 shows the correlation between polysomnographic and clinical variables and BMI. Total AHI and respiratory arousal index were significantly positively correlated with BMI (total AHI, $r=0.397$, $p<0.001$; respiratory arousal index, $r=0.336$, $p<0.001$). Mean SpO_2 was significantly negatively correlated with BMI ($r=-0.500$, $p<0.001$). The percentage of time below 90% SpO_2 and neck circumference were significantly correlated with BMI (percentage of time below 90% SpO_2, $r=0.420$, $p<0.001$; neck circumference, $r=0.619$, $p<0.001$). However, there was no significant correlation between total sleep time, the percentage of sleep stage, sleep latency, REM latency, REM sleep and supine position during sleep and BMI.

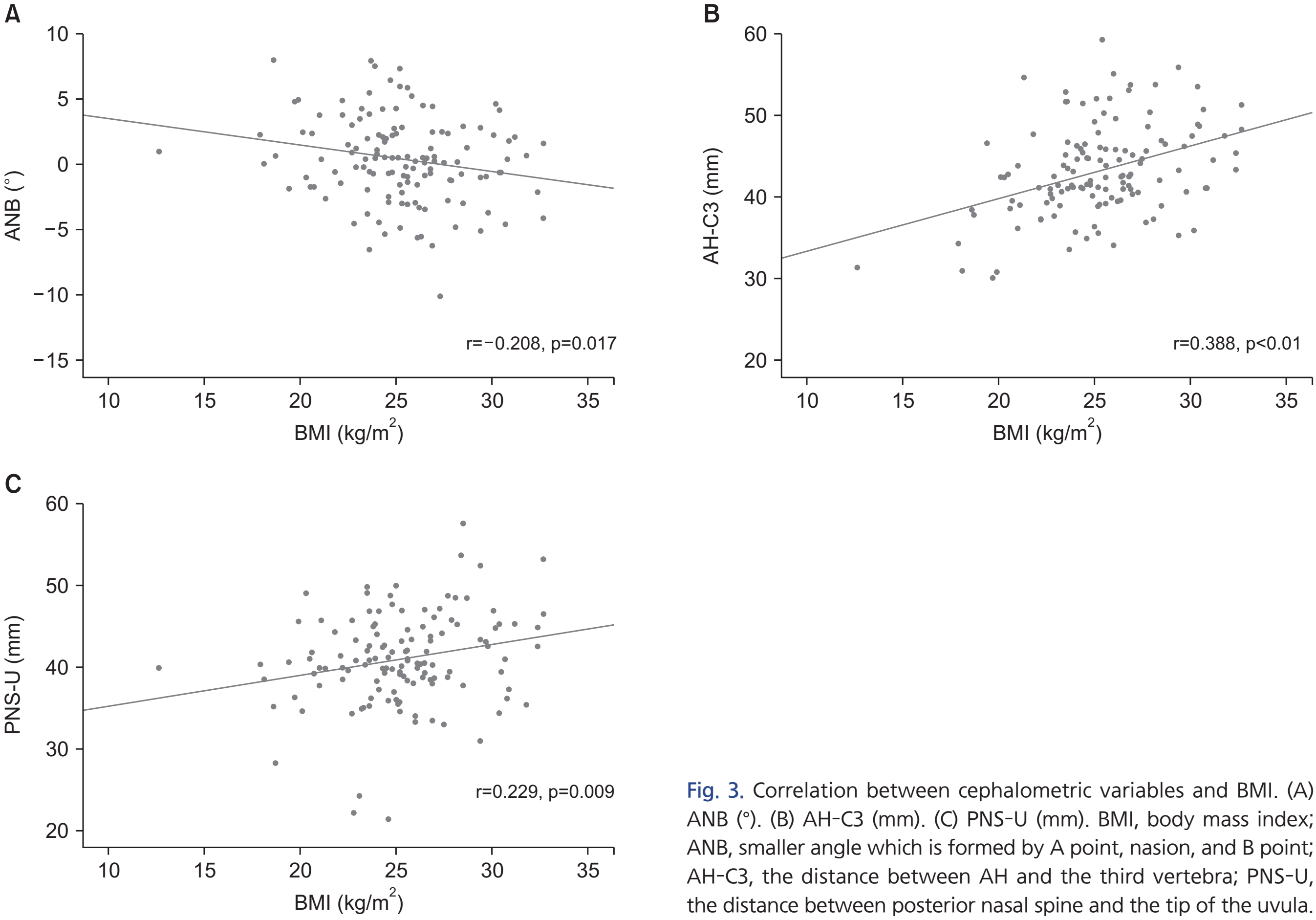

Fig. 3. Correlation between cephalometric variables and BMI. (A) ANB (°). (B) AH-C3 (mm). (C) PNS-U (mm). BMI, body mass index; ANB, smaller angle which is formed by A point, nasion, and B point; AH-C3, the distance between AH and the third vertebra; PNS-U, the distance between posterior nasal spine and the tip of the uvula.

5. Correlations between Cephalometric Parameters and BMI

Fig. 3 shows the correlation between cephalometric variables and BMI. There were significant correlation between ANB, AH-C3, PNS-U and BMI (ANB, $r=-0.208$, $p=0.017$; AH-C3, $r=0.388$, $p<0.001$; PNS-U, $r=0.229$, $p=0.009$). However, there were no significant correlations between the MPH, superior oral airway space, middle oral airway space and inferior oral airway space and BMI.

DISCUSSION

This is the first study to evaluate polysomnographic and cephalometric indices according to obesity levels using the WHO Asia-Pacific BMI criteria in Korean OSA patients. The results of this study indicated that obese patients have a higher risk for compromised changes of craniofacial skeletal and soft tissue structures and severe OSA than non-obese patients. The obese group had significantly higher overall AHI and respiratory arousal index and lower oxygen saturation levels than the normal group. Respiratory outcomes including total AHI, mean oxygen saturation and respiratory arousal index and cephalometric indices including ANB, AH-C3 and PNS-U had a significant correlation with BMI.

Obesity is an important predisposing factor for OSA, which negatively affects the anatomical and neurofunctional structures of the upper airway. In obese patients, an increased fat deposition occurs around the neck and pharynx, leading to enhanced pharyngeal extraluminal pressure and upper airway collapse [19]. And the degree of fat deposition correlates with severe OSA [20]. Furthermore, many other potential pathophysiological factors, including oxidative stress, inflammatory mediators, increased sympathetic nerve activity, leptin hormone, vascular endothelial dysfunction, and metabolic dysregulation are known to be an important factors in the relationship between obesity and OSA [21-23].

Previous studies based on PSG reported that severe obese OSA patients have more severe respiratory disturbance as higher respiratory disturbance and lower oxygen saturation than less obese OSA patients [7,9,24]. Itasaka et al. [25] divided subjects into three groups according to obesity (normal, BMI<24 kg/m^2; mild obese, 24 kg/m^2≤BMI<26.4 kg/m^2; obese, 26.4 kg/m^2≤BMI), and found that there are significant correlations between AHI, lowest oxygen saturation level and the intra-esophageal pressure and BMI. The result of our study was consistent with previous literature. Interestingly, the overweight group did not show significant differences in polysomnographic parameters when compared to the normal group except for OSA severity. This might be due to the difference in ethnicity and the BMI criteria applied in each study. It is known that Asian OSA patients have lower BMI, a smaller mandible and higher airway collapsibility compared to those from western countries, hence less affected by non-anatomical pathophysiological factors including pharyngeal muscle responsiveness, arousal threshold, and ventilatory control feedback system [11,26].

Previous studies using lateral cephalograms have revealed craniofacial anatomical characteristics in obese OSA patients. Chaves et al. [27] reported that obese men with OSA (BMI≥30 kg/m^2) presented wider and longer soft palate dimensions as well as a lower hyoid bone position. Sakakibara et al. [28] reported that obese patients with OSA (BMI≥27 kg/m^2) showed more extensive and severe soft tissue abnormalities in craniofacial bony structures than non-obese patients [28]. Yu et al. [29] reported narrower upper airway space and enlargement of the adipose tissue in obese patients with OSA (BMI≥27 kg/m^2). These findings were consistent with the result of our study showing longer length of soft palate, anterior position of hyoid bone, and smaller ANB angle in obese OSA patients. Long soft palate, larger neck circumference and lower and anterior position of the hyoid bone influence critical pharyngeal pressure, resulting in increased upper airway collapsibility [30].

The result of our study showed that the MPH distance in obese OSA patients was longer than the normal group, but it did not show significant difference. The hyoid bone serves as an anchor for tongue muscles, so the lower position of the hyoid bone is known as a compensatory mechanism to accommodate the larger tongue size [31]. The inferior and anterior position of the hyoid bone in obese OSA patients may be the result of larger tongue volume and the deposition of adipose tissue. Previous studies have revealed the correlation between the MPH distance and the neck circumference, and lower hyoid bone position in obese patients as an adaptation to large tongue size [32].

WHO International Obesity Task Force has defined BMI cut-off values for obesity in the Asian population [12]. The Asia-Pacific BMI criteria is defined as 23 kg/m^2≤BMI<25 kg/m^2 for overweight rather than 25 kg/m^2≤BMI<30 kg/m^2, and as BMI≥25 kg/m^2 for obesity rather than BMI≥30 kg/m^2. Recent studies have demonstrated that this Asia-Pacific BMI criteria to be more appropriate in reflecting the correlation between obesity and comorbid diseases and metabolic conditions in Asians than the previous WHO criteria [33,34]. The results of our study also support the validity of the Asia-Pacific BMI criteria in evaluating OSA according to obesity. A recent study also reported that obese BMI subjects have more severe indicators of OSA than low BMI subjects using this criterion in Korean OSA patients [35].

Weight loss has been shown to alleviate OSA and attenuate cardiovascular and metabolic diseases. Peppard et al. [7] reported that a 10% weight loss resulted in a 26% reduction in the AHI. Similar effects of weight loss on the severity of OSA have been shown. AHI decreased 78.3% after bariatric surgery in Australia [36]. However, weight loss is hard to achieve and maintain using conservative strategies, and there are many OSA patients who do not respond to medical and surgical weight loss therapy [37-39]. OSA is a heterogeneous and complex condition, so a multidisciplinary and integrated strategy with continuous positive airway pressure, oral appliance, maxillofacial surgery, medications, and positional therapy is required to achieve successful long-lasting treatment results.

There are some limitations of our study. First, this study lacks non-OSA control groups. It does not provide information through comparison with obese individuals without OSA. Also, its retrospective nature did not allow the involvement of potential confounding factors like alcohol intake, smoking, dietary habit, physical activity level, and laboratory findings, which could act as a source of bias affecting the results. Finally, lateral cephalometric radiographs only reveal two-dimensional images of the upper airway while awake in an erect posture. The transversal diameter of the airway is also known to correlate with prevalence and severity of OSA [24]. Therefore, future prospective controlled studies using magnetic resonance imaging or computed tomography under sedation showing three-dimensional images of the upper airway would be better to understand the pathophysiology and treatment response for OSA according to obesity.

In conclusion, obese patients have a higher risk of severe OSA as well as compromised changes of craniofacial skeletal and soft tissue structures compared to non-obese patients based on the WHO Asian-Pacific BMI criteria. Such findings could be helpful to understand the pathophysiological traits of obese OSA patients in Asia and establish multidisciplinary treatment planning for OSA.

CONFLICT OF INTEREST

Ji Hee Jang serves as an associate editor of the Journal of Oral Medicine and Pain, but she has no role in the decision to publish this article. There are no potential conflict of interest relevant to this article.

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