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Anthropometric Characteristics of Korean Patients with Obstructive Sleep Apnea

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Background and Objectives: Obesity is one of the most important risk factors for obstructive sleep apnea (OSA). There is limited evidence regarding the obesity-related anthropometric characteristics of Korean patients.

Materials and Method: Medical records of 984 patients referred to 3 tertiary referral hospitals for habitual snoring or sleep apnea were analyzed. We defined OSA as apnea-hypopnea index (AHI) ≥5 and analyzed data to determine the anthropometric characteristics of patients with OSA such as neck circumference (NC), waist circumference (WC), hip circumference (HC), and waist to hip ratio (WHR).

Results: A total of 952 patients (719 men) were included in the analysis. The main findings were: 1) BMI, WC, NC, HC, and WHR were greater among patients with OSA than among controls (AHI <5); 2) for both sexes, the proportion of patients with an OSA diagnosis increased with age; it increased steeply for women aged >50 years; 3) WC and WHR were most strongly correlated with AHI for men and women, respectively.

Conclusion: OSA is associated with anthropometric characteristics, although different patterns were observed between men and women. OSA was more strongly associated with NC or WC among men and with WHR among women.

KEY WORDS: obstructive sleep apnea · Body mass index · Neck circumference · Waist circumference · Waist to hip ratio.

INTRODUCTION

Obstructive sleep apnea (OSA) is characterized by repetitive upper airway collapse during sleep, which induces frequent arousals and oxygen desaturation.[1)] OSA is associated with a range of symptoms and conditions, such as fatigue, daytime somnolence, headache, myocardial infarction, arrhythmias, stroke, and an increased incidence of motor vehicle accidents.[1)] Therefore, accurate diagnosis and treatment of OSA is crucial to improve quality of life and to reduce the risk of associated morbidity and mortality.[1)2)]

Varying prevalence rates of OSA have been reported, although prevalence is approximately 6−17% when OSA is defined as greater than 15 obstructed breathing events per

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hour during sleep.[3] OSA prevalence increases with age and is significantly higher among men. For women, the prevalence increases after menopause.[3] It has been postulated that the worldwide prevalence of OSA has been increasing with the global rise of obesity.[3] While the exact underlying pathophysiology is unknown, obesity is thought to reduce the diameter of the upper airway and increase its collapsibility.[3]

Several anthropometric measurements, such as body mass index (BMI), neck circumference (NC), waist circumference (WC), and waist-hip ratio (WHR) have been frequently used to investigate the association between obesity and OSA.[4-23] However, variable findings have been reported, according to age, sex, and ethnicity. To date, most studies have involved small numbers of subjects derived from a single medical center. In this study, we evaluated demographic and anthropometric characteristic of patients with OSA. To increase the number of study subjects and achieve a more definitive conclusion, we collected the medical records from 3 tertiary referral hospitals in Korea and analyzed a range of variables.

MATERIALS AND METHODS

This study was conducted by analyzing the medical records of 1,130 adults (age ≥19 years) referred to 3 tertiary referral hospitals due to habitual snoring or sleep apnea. Patients had been investigated by using standard polysomnography (PSG) over the preceding 2 years (2015−2016). We excluded foreign subjects and those with a past history of upper airway surgery. PSG was performed and scores were entered manually by qualified sleep technicians using the 2012 American Academy of Sleep Medicine guidelines. Results were reviewed by sleep specialists. We identified the following variables from the medical records:

1) Basic property variables: age, sex, smoking, hypertension, diabetes, Epworth sleepiness scale (ESS), Pittsburgh sleep quality index (PSQI)

2) Anthropometric variables: height, weight, BMI, NC, WC, hip circumference (HC), WHR

3) Sleep-related variables: total sleep time, sleep efficiency, N3 sleep percentage (N3), REM sleep percentage, arousal index

4) Respiratory variables: apnea index, hypopnea index, apnea-hypopnea index (AHI), supine AHI, minimum O_2 saturation (Min SpO_2), mean O_2 saturation (Mean SpO_2), 3% oxygen desaturation index (ODI3)

We compared patients with OSA (defined as AHI ≥5) with simple snorers (defined as AHI <5).

Statistical analysis

The student t-test was used for all continuous variables, and the chi-square test was used for dichotomous variables. We also calculated the correlation coefficient (CC), after adjusting for age, between AHI and anthropometric variables, including BMI, NC, WC, and WHR using Pearson's correlation. To identify the diagnostic value of anthropometric variables, the receiving operating characteristic (ROC) curve was traced for the BMI, NC, WC, and WHR, respectively. Furthermore, the cut-off value for each anthropometric variable was presented based on Youden's index. Statistical significance was set at $p<0.05$. The Statistical Package for the Social Sciences, IBM SPSS Statistics 22 (IBM, Armonk, New York. USA) was used for statistical analysis.

RESULTS

Finally, we analyzed 952 patients (719 men and 233 women). Out of 719 men, 649 (90.3%) were diagnosed with OSA, while 173 (74.2%) out of 233 women were diagnosed with OSA.

Subject demographics

Age, prevalence of hypertension, and all the obesity-related anthropometric variables were significantly greater among patients with OSA compared to simple snorers. However, there were no differences between the two groups in subjective daytime sleepiness (ESS) and sleep quality (PSQI). Deep sleep (N3) was significantly reduced among patients with OSA, although this finding was only observed among men, while the arousal index was significantly greater for both men and women. There were significant differences between the two groups in all respiratory indexes, including AHI and ODI3. The results are summarized in Table 1.

Prevalence of age-related OSA

Overall, subjects aged 50-59 years were most commonly referred to hospital, and the proportion of patients with OSA increased significantly with age ($p<0.001$, Fig. 1). However, there were considerable differences between men and women in the distribution of increased OSA prevalence with age. For men, the percentage of patients with OSA was the lowest for those aged 19−29 years (79%), gradually increas-

Table 1. Sex-specific characteristics of Korean patients with obstructive sleep apnea

Variable	Men			Women		
	OSA (n=649)	Simple snorer (n=70)	p	OSA (n=173)	Simple snorer (n=60)	p
Clinical factor						
Age (year)	44.8±13.2	36.0±12.3	<0.001	54.5±11.9	41.0±13.1	<0.001
Smoking	285 (43.9%)	29 (41.4%)	0.786	4 (2.3%)	5 (8.3%)	0.09
HTN	192 (29.6%)	8 (11.4%)	0.002	61 (35.3%)	3 (5.0%)	<0.001
DM	62 (9.6%)	2 (2.9%)	0.099	18 (10.4%)	0 (0.0%)	0.02
ESS	8.3±4.5	9.2±4.8	0.141	8.0±5.0	8.4±5.7	0.846
PSQI	7.5±3.4	7.6±3.4	0.738	7.7±3.7	8.4±4.1	0.261
Anthropometry						
Weight (kg)	78.4±13.0	71.6±11.0	<0.001	63.2±11.0	58.2±7.5	0.001
BMI (kg/m^2)	26.7±3.8	24.3±3.0	<0.001	25.9±4.3	23.0±3.2	<0.001
NC (cm)	39.8±4.3	36.8±3.5	<0.001	35.5±8.6	34.0±4.0	0.01
WC (cm)	94.2±9.9	87.4±8.3	<0.001	89.6±9.7	82.1±8.1	<0.001
HC (cm)	99.7±7.8	96.7±6.5	0.007	97.0±7.3	94.1±6.0	0.005
WHR	0.94±0.06	0.90±0.05	<0.001	0.92±0.06	0.87±0.06	<0.001
Sleep index						
TST (min)	350.4±72.6	362.4±77.5	0.477	362.5±74.6	339.7±71.8	0.041
SE (%)	84.5±13.4	87.7±10.3	0.077	85.3±11.4	85.7±10.6	0.993
N3 (%)	11.6±11.6	17.6±17.8	0.024	18.0±14.5	17.0±17.5	0.388
REM	16.0±8.3	16.9±8.9	0.276	16.5±7.9	16.8±7.9	0.809
Arousal index	34.3±20.9	11.7±10.2	<0.001	26.7±16.4	10.0±6.6	<0.001
Respiratory index						
AI	22.5±23.3	0.5±0.6	<0.001	11.6±16.5	0.5±0.6	<0.001
HI	13.5±10.6	1.5±1.3	<0.001	15.4±12.3	1.1±1.2	<0.001
AHI	35.8±24.7	2.0±1.5	<0.001	27.0±21.0	1.7±1.5	<0.001
Supine AHI	46.1±28.5	2.6±2.6	<0.001	35.2±25.8	2.4±2.2	<0.001
Minimum SaO_2 (%)	80.7±9.1	90.9±4.1	<0.001	83.3±7.2	92.0±3.2	<0.001
Mean SaO_2 (%)	95.0±2.7	96.7±1.1	<0.001	95.8±1.8	97.4±1.1	<0.001
ODI3	31.6±25.1	2.1±1.7	<0.001	22.7±20.8	1.5±1.6	<0.001

p-values were calculated by independent t-test or Mann-Whitney U test for continuous variables and chi-square test or Fisher's exact test for categorical variables. Data were presented as mean±standard deviation for continuous variables and frequency (percentage) for categorical variables. OSA: obstructive sleep apnea, HTN: hypertension, DM: diabetes mellitus, ESS: Epworth sleepiness scale, PSQI: Pittsburgh sleep quality index, BMI: body mass index, NC: neck circumference, WC: waist circumference, HC: hip circumference, WHR: waist-to-hip ratio, TST: total sleep time, SE: sleep efficiency, N3: non-REM stage 3, REM: rapid eye movement, SaO_2: arterial oxygen saturation, ODI: oxygen desaturation index

ing to 100% for those aged ≥70 years (Fig. 1). However, for women, the percentage of patients with OSA was <50% among those aged <49 years, rapidly increasing to 92.3% among those aged 50−59 years and decreasing gradually thereafter (Fig. 1).

Correlation between the AHI and anthropometric variables

After adjusting for age, all anthropometric variables were strongly correlated with the AHI, except for NC among women (CC: 0.076). The strongest correlations with the AHI were observed for WC among men (CC: 0.520, p<0.001) and for WHR among women (CC: 0.364, p<0.001). The results are summarized in Table 2.

ROC curve of anthropometric variables for the diagnosis of OSA

ROC curves for OSA diagnosis were calculated to estimate the diagnostic value of each anthropometric variable. For men, the area under curve (AUC) of NC was the greatest (0.74), although, there was little difference among BMI (0.69), NC, WC (0.70), and WHR (0.71) (Fig. 2). For women, the AUC of WHR was the greatest (0.75), followed by the AUC of WC and BMI (each 0.72), and while the AUC of NC was 0.61 (Fig. 2). Cut-off values for each anthropometric variable are presented in Table 3.

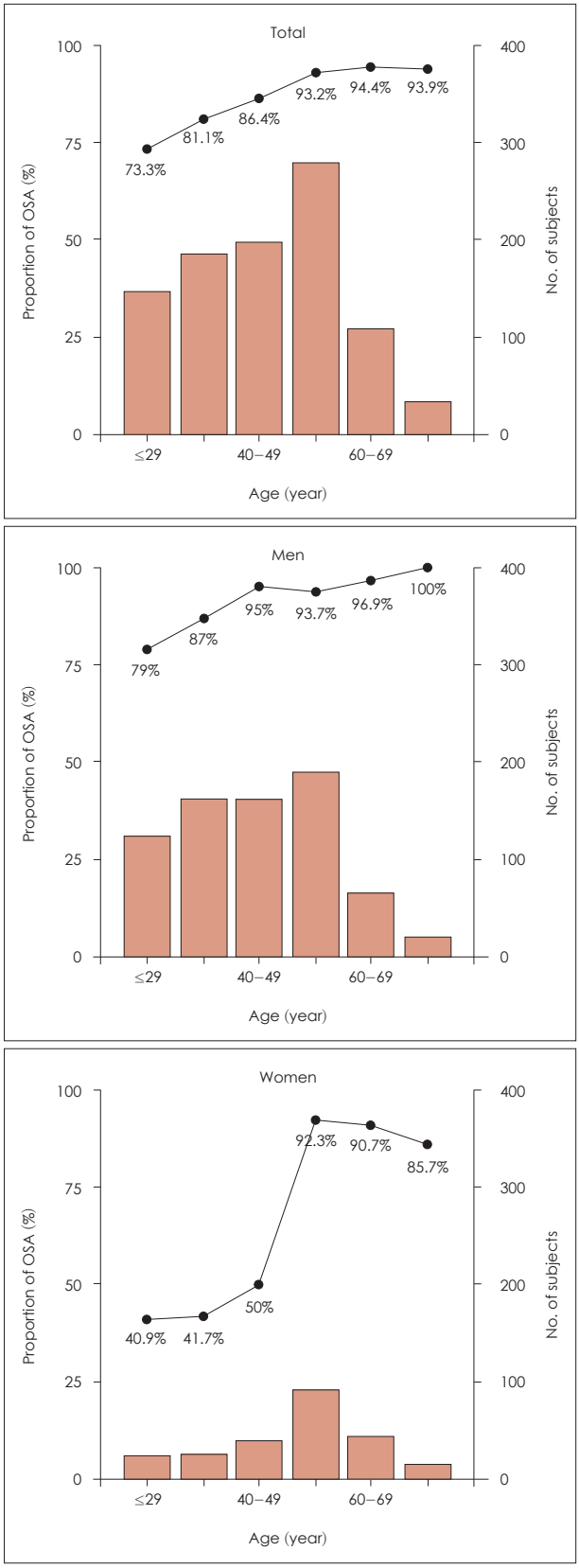

Fig. 1. Frequency of obstructive sleep apnea according to sex and age.

Table 2. Correlation of anthropometric variables with AHI after adjusting age

Parameter	All (n=952)	Men (n=719)	Women (n=233)
BMI	0.495**	0.517**	0.337**
NC	0.283**	0.328**	0.076
WC	0.523**	0.520**	0.342**
HC	0.403**	0.420**	0.188*
WHR	0.428**	0.385**	0.364**

Values are Pearson's correlation coefficient. *: p<0.01, *: p<0.001. BMI: body mass index, NC: neck circumference, WC: waist circumference, HC: hip circumference, WHR: waist-to-hip ratio

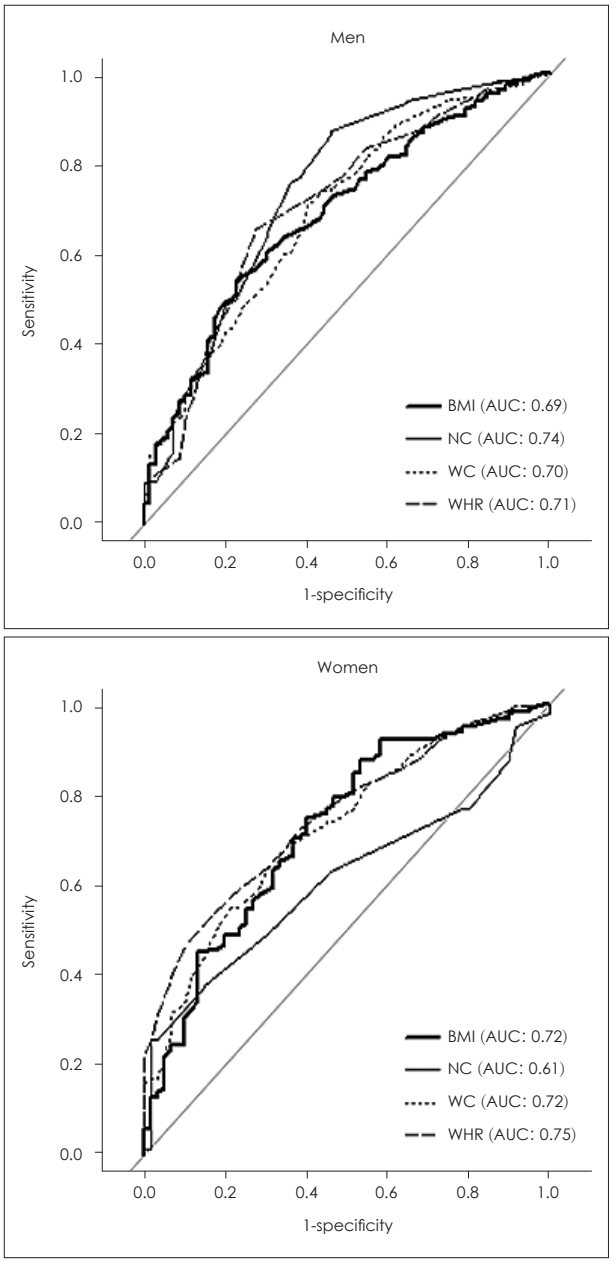

Fig. 2. ROC curves of anthropometric variables for obstructive sleep apnea in men and women.

Table 3. Diagnostic performance for OSA

Variable	Men					Women				
	THR*	SE	SP	AUC (95%CI)	p	THR*	SE	SP	AUC (95%CI)	p
BMI (kg/m^2)	≥23.35	0.54	0.77	0.69 (0.63–0.75)	<0.001	≥23.15	0.75	0.6	0.72 (0.65–0.80)	<0.001
NC (cm)	≥36.25	0.87	0.54	0.74 (0.67–0.81)	<0.001	≥36.90	0.25	0.98	0.61 (0.54–0.68)	0.175
WC (cm)	≥89.25	0.71	0.6	0.7 (0.63–0.76)	<0.001	≥85.50	0.65	0.68	0.72 (0.65–0.79)	<0.001
HC (cm)	≥98.30	0.55	0.59	0.6 (0.53–0.67)	0.002	≥95.50	0.58	0.65	0.62 (0.54–0.70)	0.007
WHR	≥0.925	0.65	0.73	0.71 (0.64–0.77)	<0.001	≥0.935	0.46	0.9	0.75 (0.68–0.81)	<0.001

Sensitivity and specificity were calculated using the threshold obtained by Youden's index. *: The threshold was derived by Youden's index. BMI: body mass index, NC: neck circumference, WC: waist circumference, HC: hip circumference, WHR: waist-hip ratio, SE: sensitivity, SP: specificity, AUC: area under the curve, CI: confidence interval, THR: threshold

DISCUSSION

It is well known that obesity has a significant impact on the development of OSA, although there is limited or conflicting evidence to support this.[4-23] In our previous study, we conducted a meta-analysis based on 19 articles and involving 2,966 subjects to establish the association between obesity and OSA in our previous study.[24] The key findings were that there were no differences in BMI, WC, and WHR between patients with OSA and simple snorers, after adjusting for publication bias, while the NC was greater among patients with OSA than among simple snorers. Furthermore, there were no differences in anthropometric phenotypes (BMI, NC, WC, and WHR) between Asian and Caucasian patients with OSA.[24] However, there were a number of limitations to the meta-analysis, such as the use of different diagnostic criteria for OSA among studies and no consideration of age and sex. To overcome these limitations, we collected clinical data from three tertiary referral hospitals, increased the number of subjects as far as possible, and performed a precise analysis according to age and sex.[22]

This study shows that all anthropometric variables, including BMI, NC, WC, HC, and WHR, are significantly greater among patients with OSA compared to simple snorers for both men and women. However, it is difficult to conclude that these anthropometric differences affect the occurrence of OSA because patients with OSA were significantly older than those in the simple snorer group, with a mean difference of 8.8 years for men and 13.5 years for women. It is well recognized that, generally, age is associated with an increase in weight, correlating with an increased risk of developing OSA. Therefore, it is important to highlight that age is likely a confounding variable. However, Table 2 shows that all anthropometric variables were strongly correlated with AHI after adjusting for age, which means that even taking into account the effects of age, anthropometric variables are associated with OSA. The correlation between AHI and anthropometric variables was considerably stronger among men than among women. The most strongly correlated variable was WC for men and WHR for women. The most noticeable difference between the sexes was observed in the correlation between AHI and NC: although NC significantly correlated with AHI among men, but the correlation was not significant among women. Differences between men and women have been reported in other studies and have generally been attributed to differences in the musculoskeletal system, fat distribution, or hormones between the sexes.[22,25]

The number of men referred was significantly greater than that of women. Among men, the number gradually increased for subjects in their 20s through to their 50s. However, referrals significantly decreased among men in their 60s. The underlying reason for this finding is not clear, although we postulate that men before their 60s are socially active and financially secure and, therefore, motivated to attend hospital. However, once they retire and become financially vulnerable (after 60s), fewer men are able to attend hospital. The percentage of patients with OSA increases with age.[3] In this study, 79% of patients in their 20s were diagnosed with OSA; this number increased steadily with age and reached 100% for patients in their 70s. Among women, these trends are considerably different. The number of women attending hospital is low under the age of 50, significant among women in their 50s, and rapidly declines thereafter. This distribution could be explained by the fact that the incidence of OSA among women is lower than that in men, particularly before menopause. However, another reason may be that Korean women, particularly young women, are very dismissive about having a snoring habit, so they do not attend hospital. The percentage of patients with OSA is less than 50% by the age of 50, but increases rapidly to 92.3%

for women in their 50s and gradually decreases thereafter. This finding may be closely related to the fact that the mean age of menopause among Korean women is 49.7 years.[26]

CONCLUSION

OSA is associated with anthropometric characteristics among men and women. However, the predictive power of anthropometric characteristics is different between the sexes. Among men, NC and WC are better predictors of the risk of developing OSA, while among women WHR is the better predictor.

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