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# Association between obstructive sleep apnea syndrome and waist-to-height ratio

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## Abstract

**Purpose** Obesity is among the known risk factors for obstructive sleep apnea syndrome (OSAS). In this study, our aim was to investigate the correlation of waist-to-height ratio, an indicator of central obesity, with presence and severity of OSAS; to compare the use of this ratio with the use of waist circumference and body mass index (BMI); and to determine OSAS-related cutoff values.

**Methods** The patient records were retrospectively analyzed for whom a polysomnography was conducted at our sleep. Sex, age, Apnea-Hypopnea Index (AHI), waist circumference, height, and BMI values of those patients were recorded. AHI scores were used to classify severity of OSAS.

**Results** The study included 437 OSAS patients and 72 control cases. Out of the patient group, OSAS was severe in 208 (47%) patients, moderate in 124 (28%), and mild in 105 (24%) of them. In the group of OSAS patients, waist-to-height ratio, waist circumference, and BMI were higher compared to the control group with a further difference of all three parameters among severe, moderate, mild OSAS, and controls both in males and females. Cutoff values for OSAS of females were 95.5 cm for waist circumference, 0.595 for waist-to-height ratio, and 27.75 for BMI whereas the cutoff values of males were 100.5 cm, 0.575, and 27.75, respectively.

**Conclusions** A high value of waist circumference, waist-to-height ratio, and BMI is associated with the presence and severity of OSAS. We have determined the cutoff values of the studied anthropometric measurements in both sexes for OSAS and severe OSAS.

**Keywords** Obstructive sleep apnea · Obesity · Anthropometric measurements · Waist circumference · Waist-to-height ratio · Body mass index

## Introduction

Obstructive sleep apnea syndrome (OSAS) is the most common sleep-related respiratory disorder characterized with a partial or total collapse of the upper respiratory tract during sleep. OSAS causes oxygen desaturation and fragmented sleep during the sleeping period which results in daytime hypersomnolence, and cognitive impact [1, 2]. It has also been associated with cardiovascular and metabolic diseases [3–5]. Cardiovascular complications may arise as a result of OSAS, if left untreated for a long term [2, 6]. An increased mortality risk has been indicated in studies on moderate and severe OSAS. Early diagnosis and treatment is therefore important to avoid sequelae of untreated obstructive sleep apnea [2, 7]. Polysomnography has been established as the gold standard in the diagnosis of OSAS. However, as this investigation is limited in availability, expensive, and taking a long time to accomplish, it is crucial to identify the high-risk population and to prioritize them regarding OSAS diagnostics.

Obesity features as an important risk factor for OSAS development [2, 3]. In obese individuals, loss of muscle strength in the upper respiratory tract due to fat accumulation on the muscles decreased airway diameter as a result of mass effect, and mechanisms such as tracheal traction are blamed for the increased OSAS risk [3]. Obesity reduces total respiratory compliance by decreasing both chest wall compliance and lung compliance. Consequently, while functional residual capacity, vital capacity, and total lung capacity diminish, airway

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**Table 1** Anthropometric measurements and AHI scores of OSAS patients and controls

| | WC (cm) mean ± SD $p < 0.001$* | WHR mean ± SD $p < 0.001$* | BMI (kg/m$^2$) mean ± SD $p < 0.001$* | AHI scores median (min-max) $p < 0.001^+$ |
|---|---|---|---|---|
| OSAS | 107.93 ± 11.96 | 0.63 ± 0.08 | 30.89 ± 5.06 | 28.9 (5–118.2) |
| Control | 91.67 ± 12.00 | 0.55 ± 0.07 | 25.94 ± 3.92 | 2.15 (0–4.9) |

*WC* waist circumference, *WHR* waist-to-height ratio, *Welch *t* test, $^+$ Wilcoxon-Mann-Whitney test

resistance increases [8]. In addition to weight gain, fat distribution in the body holds a substantial role in OSAS development. For this reason, various anthropometric measurements including BMI, neck circumference, waist circumference, and waist-hip ratio are used throughout the follow-up of OSAS patients [2]. In previous studies from Turkey and Korea, cutoff values of waist circumference, neck circumference, and BMI for determine to OSAS have been submitted [9, 10]. Banhiran et al. reported waist-to-height ratio is the independent predictor for moderate to severe OSAS in male gender between BMI, neck circumference, neck to height ratio, waist circumference, and waist-to-height ratio [11].

In this study, our aim was to investigate the correlation of waist-to-height ratio, an indicator of central obesity, with presence and severity of OSAS; to compare the usage of this ratio with that of waist circumference and BMI; and to determine cutoff values in the decision of OSAS diagnosis and severity.

## Method

The patient records were retrospectively analyzed for whom a polysomnography (PSG) was conducted at the sleep laboratory of Mugla Sitki Kocman University, Hospital of Faculty of Medicine, during the time period of January 1, 2014 and December 31, 2016. This study has been approved by the local ethics committee.

The patients included in the study were over 18 years old. Patients with neuromuscular disease, craniofacial disorder, hypothyroidism, congestive cardiac failure, chronic renal failure, and chronic pulmonary disease were not included in the study. Sex, age, Apnea-Hypopnea Index (AHI), waist circumference, height, and BMI value of the patients were recorded. Based on the records, waist-to-height ratio was calculated for each patient. (Waist circumference of patients refers to the measurement along the mid-point between the lower edge of the lowest rib and the anterior superior iliac crest, and is recorded in “cm”.) Body mass index is calculated by body weight (in kg)/height$^2$ (in m$^2$). Polysomnography records of all patients were taken with an Embla N7000 device. Recording and scoring was performed in accordance with “The AASM Manual for the Scoring of Sleep and Associated Events” [12]. AHI was taken as total number of apneas and hypopneas/sleep duration in hours. Patients with an AHI value of equal to or greater than 5 were diagnosed as having OSAS. Among them, further classification was made as mild ($5 \leq AHI \leq 15$), moderate ($15 < AHI < 30$), and severe ($AHI \geq 30$) OSAS. Among the participants, suitable for the study, with $AHI < 5$ were also included as the control group.

## Statistical analysis

The Welch *t* test and Wilcoxon-Mann-Whitney test were used to determine whether there was a difference in waist-to-height ratio, waist circumference, and BMI values between patients with OSAS and healthy individuals. Summary statistics of data with normal distribution, i.e., corresponding to the Welch *t* test, were expressed as mean ± standard deviation. For non-normal data, it is expressed as median, minimum, and maximum. In addition, ANOVA and Kruskal-Wallis tests were applied for multiple comparisons between severe, moderate, and mild cases and controls. The correlation between the studied three anthropometric measurements with AHI values was expressed by Pearson’s correlation coefficient. In order to obtain a better linear relationship, square root transformation was applied on AHI

**Table 2** Anthropometric measurements and AHI scores of OSAS patients with respect to severity of their conditions

| | WC (cm) mean ± SD $p < 0.001$** | WHR mean ± SD $p < 0.001$** | BMI (kg/m$^2$) mean ± SD $p < 0.001$** | AHI scores median (min-max) $p < 0.001^{++}$ |
|---|---|---|---|---|
| Severe OSAS | 111.74 ± 12.47 | 0.65 ± 0.08 | 31.28 ± 5.80 | 59.9 (31.1–118.2) |
| Moderate OSAS | 106.63 ± 9.60 | 0.62 ± 0.07 | 30.28 ± 3.69 | 22.25 (15.4–30) |
| Mild OSAS | 101.92 ± 10.66 | 0.61 ± 0.08 | 28.87 ± 4.00 | 9.2 (5–15) |
| Control | 91.67 ± 12.00 | 0.55 ± 0.07 | 25.94 ± 3.92 | 2.15 (0–4.9) |

*WC* waist circumference, *WHR* waist-to-height ratio, **ANOVA, $^{++}$ Kruskal-Wallis test

**Table 3** Anthropometric measurements and AHI scores of OSAS patients and controls for females and males

| | | WC (cm) mean ± SD $p < 0.001$* | WHR mean ± SD $p < 0.001$* | BMI (kg/m$^2$) mean ± SD $p < 0.001$* | AHI scores median (min-max) $p < 0.001^+$ |
|---|---|---|---|---|---|
| Females | OSAS | 106.60 ± 12.62 | 0.66 ± 0.08 | 31.77 ± 6.14 | 20.3 (5–102.3) |
| | Control | 88.14 ± 11.63 | 0.54 ± 0.07 | 25.54 ± 4.30 | 1.35 (0–4.8) |
| Males | OSAS | 108.40 ± 11.70 | 0.62 ± 0.07 | 30.58 ± 4.60 | 32.7 (5.5–118.2) |
| | Control | 95.21 ± 11.45 | 0.55 ± 0.06 | 26.35 ± 3.52 | 2.8 (0.1–4.9) |

*WC* waist circumference, *WHR* waist-to-height ratio, *Welch *t* test, $^+$ Wilcoxon-Mann-Whitney test

values. We used age-adjusted logistic regression and adjto to assess the association between these three parameters and OSAS. ROC analysis was used to calculate the cutoff values in order to detect patients with a high risk of OSAS. To determine any relationship between sex, and presence and severity of OSAS, chi-square test was used. All the analyses were repeated separately for females and males. A $p$ value of < 0.05 was considered statistically significant. All computational analyses were performed using the statistical software R [13].

## Results

There were 437 patients with OSAS and 72 cases in control group. Two hundred eight (47%) of the patients had severe OSAS (females $n = 41$, males $n = 167$), 124 (28%) had moderate OSAS (females $n = 28$, males $n = 96$), and 105 (24%) had mild OSAS (females $n = 45$, males $n = 60$). There were 36 females and 36 male participants who were not diagnosed with OSAS. Incidence of severe and moderate OSAS in males was significantly higher than that in females ($p < 0.001$, chi-square test).

The mean age of patients with OSAS was 49.27 ± 12.01 and those without OSAS was 39.35 ± 12.09. There was a significant difference between them ($p < 0.001$, Welch $t$ test). The mean age of female (51.87 ± 11.70) and male patients (48.35 ± 12.00) with OSAS was significantly higher than those without OSAS (40.22 ± 11.82 and 38.47 ± 12.45 respectively) ($p < 0.001$, Welch $t$ test).

We used logistic regression to assess the association between waist circumference, waist-to-height ratio, BMI, and incident OSAS adjusting for age. Logistic regression suggested that all three anthropometric measurements are significant for predicting the likelihood of having OSAS, adjusted for age ($p < 0.001$).

Waist circumference, waist-to-height ratio, BMI, and AHI scores of patients with OSAS were significantly higher than those without OSAS (Table 1).

The AHI score was correlated with waist circumference ($r = 0.40$, $p < 0.001$), waist-to-height ratio ($r = 0.32$, $p < 0.001$), and BMI ($r = 0.33$, $p < 0.001$) in OSAS patients. When all values were taken into consideration, the highest correlation was found between waist circumference and AHI but there was no significant difference with the others.

OSAS was severely observed in 208 (47%), moderately in 124 (28%), mildly in 105 (24%) patients, and there were 72 participants in the control group. There were significant differences between these four groups in terms of studied anthropometric measurements and AHI scores (Table 2, all $p$ value < 0.001).

**Table 4** Anthropometric measurements and AHI scores of OSAS patients and controls with respect to severity of their conditions for females and males

| | | WC (cm) mean ± SD $p < 0.001$** | WHR mean ± SD $p < 0.001$** | BMI (kg/m$^2$) mean ± SD $p < 0.001$** | AHI scores median (min-max) $p < 0.001^{++}$ |
|---|---|---|---|---|---|
| Females | Severe OSAS | 112.55 ± 11.42 | 0.70 ± 0.07 | 35.15 ± 7.10 | 58 (32.3–102.3) |
| | Moderate OSAS | 106.04 ± 9.67 | 0.64 ± 0.06 | 30.67 ± 4.50 | 21.65 (16.8–29.4) |
| | Mild OSAS | 101.53 ± 13.17 | 0.63 ± 0.09 | 29.38 ± 4.60 | 9 (5–14.2) |
| | Control | 88.14 ± 11.63 | 0.54 ± 0.07 | 25.54 ± 4.30 | 1.35 (0–4.8) |
| Males | Severe OSAS | 111.54 ± 12.74 | 0.64 ± 0.07 | 31.58 ± 5.22 | 7 (0–22) |
| | Moderate OSAS | 106.81 ± 9.62 | 0.61 ± 0.07 | 30.17 ± 3.43 | 5.5 (0–20) |
| | Mild OSAS | 102.22 ± 8.42 | 0.59 ± 0.06 | 28.48 ± 3.48 | 7 (1–22) |
| | Control | 95.21 ± 11.45 | 0.55 ± 0.06 | 26.35 ± 3.52 | 2.8 (0.1–4.9) |

*WC* waist circumference, *WHR* waist-to-height ratio, **ANOVA, $^{++}$ Kruskal-Wallis test

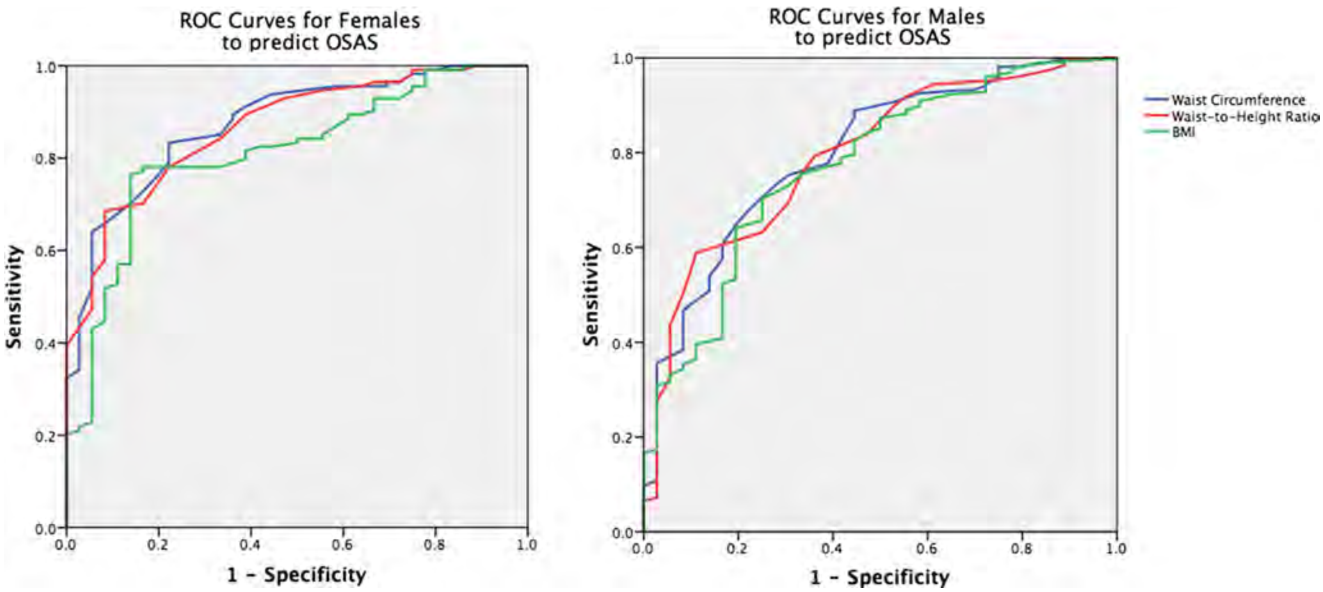


**Fig. 1** ROC curves for females and males to predict OSAS. Each point on the ROC curve represents a sensitivity/specificity pair corresponding to a particular cutoff value

Waist circumference, waist-to-height ratio, BMI, and AHI values of both female and male patients with OSAS were significantly higher than those without OSAS. (Table 3, all $p$ values < 0.001).

The correlation between the studied three anthropometric measurements with AHI values was analyzed for females and males separately. In the female population, the highest correlation was found between waist circumference and AHI ($r = 0.61$, $p < 0.001$). Waist-to-height ratio and BMI were also found to be highly correlated with AHI score (both $r = 0.60$, $p < 0.001$). In the male population, there was the same pattern in terms of the correlations. However, the association was weaker than that in females ($r = 0.46$, $p < 0.001$ for waist circumference; $r = 0.44$, $p < 0.001$ for waist-to-height ratio; $r = 0.39$, $p < 0.001$ for BMI).

There were significant differences among severe OSAS, moderate OSAS, mild OSAS, and controls in terms of waist circumference, waist-to-height ratio, and BMI in males and females (Table 4, all $p$ values < 0.001).

ROC analysis was used to determine the cutoff values in order to detect patients with a high risk of OSAS (Fig. 1). High AUC values in Table 5 suggest that waist circumference, waist-to-height ratio, and BMI are "good" at classifying high risk for OSAS. Females with waist circumference greater than 95.5 cm (sensitivity = 84%) and males measured to have a waist wider than 100.5 cm (sensitivity = 75%) and females with waist-to-height ratio greater than 0.595 (sensitivity = 78%) and males with a measurement greater than 0.575 (sensitivity = 76%) were found to be at high risk for OSAS. Both females and males with BMI greater than 27.75 kg/m$^2$ (sensitivity = 78% and 73%, respectively) were also found to be at high risk for OSAS.

In addition, we also determined the cutoff values in order to detect patients with a high risk of severe OSAS (Fig. 2, Table 6). Females with waist circumference greater than 104.5 cm (sensitivity = 76%) and males with waist circumference greater than 106.5 cm (sensitivity = 64%); females with waist-to-height ratio greater than 0.635 (sensitivity = 81%) and males with waist-to-height ratio greater than 0.605 (sensitivity = 69%); and females with BMI greater than 29.9 kg/m$^2$ (sensitivity = 81%) and males with BMI greater than 29.6 kg/m$^2$ (sensitivity = 61%) were found to be at high risk for severe OSAS.

**Table 5** Cutoff values to classify the high risk for OSAS; their sensitivities and specificities; and the area under the ROC curves (AUC)

| | | Cutoff value | Sensitivity (%) | Specificity (%) | AUC |
|---|---|---|---|---|---|
| Females | WC (cm) | 95.5 | 84 | 78 | 0.88 |
| | WHR | 0.595 | 78 | 78 | 0.87 |
| | BMI (kg/m$^2$) | 27.75 | 78 | 83 | 0.81 |
| Males | WC (cm) | 100.5 | 75 | 69 | 0.80 |
| | WHR | 0.575 | 76 | 67 | 0.79 |
| | BMI (kg/m$^2$) | 27.75 | 73 | 69 | 0.77 |

*WC* waist circumference, *WHR* waist-to-height ratio

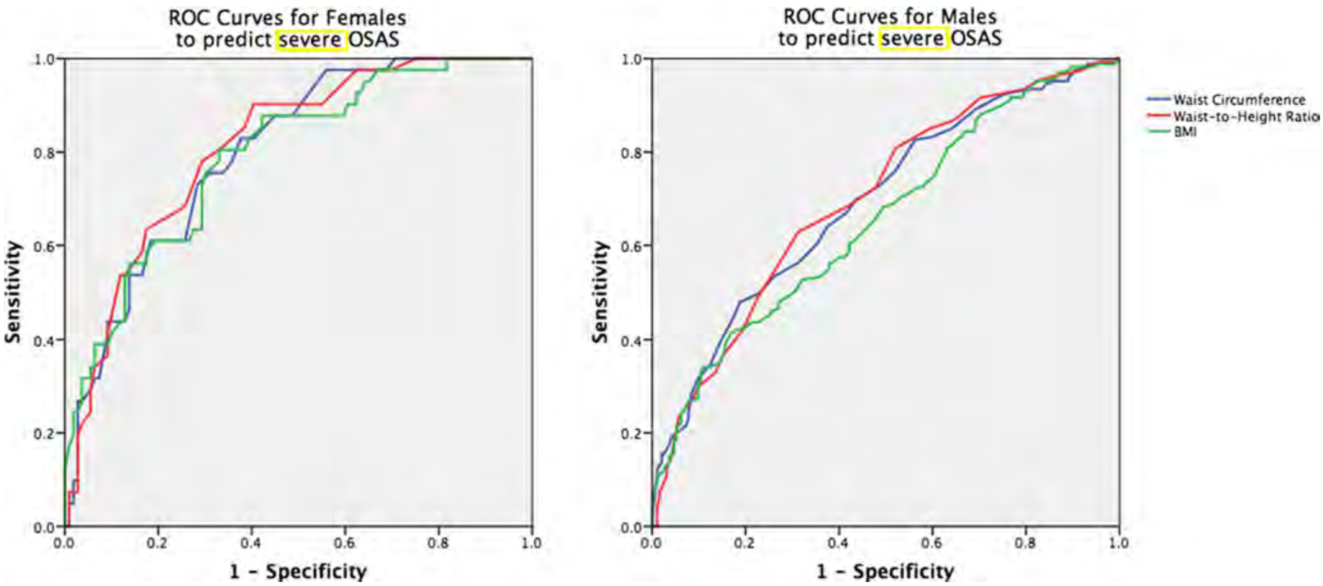


**Fig. 2** ROC curves for females and males to predict severe OSAS. Each point on the ROC curve represents a sensitivity/specificity pair corresponding to a particular cutoff value

## Discussion

Obesity is one of the most important risk factors for OSAS. A weight gain by 10% over the limit of normal leads to a 6-fold increase of OSAS risk [3]. Likewise, individuals with a BMI > 28 are at a 8- to 10-fold increased risk of OSAS [8, 14].

Recently, instead of an increased overall body fat ratio, the increase in the central region is suggested to have a pivotal role in OSAS [3]. Therefore, despite the conventional and common use of BMI in monitoring OSAS, anthropometric measurements such as waist circumference, neck circumference, and waist-hip ratio have gained importance [2, 3, 15]. In our study, waist circumference and waist-to-height ratio, which are indicators of central obesity, as well as BMI, were measured to be higher in OSAS patients, together with an increase in all three parameters with the increased disease severity. Correlation analysis of three anthropometric measurements with AHI did not reveal any difference in either of the sex.

Our results demonstrate an increased risk in both males and females in the event of a BMI over 27.75 kg/m$^2$ (sensitivity 78%, specificity 83% in females; sensitivity 73%, specificity 69% in males). A previous study implemented in Turkey has figured out those values as 27.77 kg/m$^2$ in women and 28.93 kg/m$^2$ in men [9]. In a Korean study, on the other hand, OSAS cutoff values were stated to be 23.05 kg/m$^2$ in women and 24.95 kg/m$^2$ in men for the Korean population [10]. In the study by Soylu et al., waist circumference cutoff values to be considered as a risk factor for OSAS for Turkish population were 105 cm in males and 101 cm in females [9]. A Korean study suggests waist circumference values greater than 76.5 cm in women and 88.5 cm in men pose a risk for OSAS [10]. In our study, the cutoff values beyond which there is an increased risk of OSAS were 95.5 cm in women (sensitivity 84%, specificity 78%) and 100.5 cm in males (sensitivity 75%, specificity 69%). Anthropometric measurements and their clinical effects exhibit racial variances. Different cutoff

**Table 6** Cutoff values to separate the high risk for severe OSAS; their sensitivities and specificities; and the area under the ROC curves (AUC)

| | | Cutoff value | Sensitivity (%) | Specificity (%) | AUC |
|---|---|---|---|---|---|
| Females | WC (cm) | 104.5 | 76 | 69 | 0.80 |
| | WHR | 0.635 | 81 | 67 | 0.81 |
| | BMI (kg/m$^2$) | 29.9 | 81 | 67 | 0.79 |
| Males | WC (cm) | 106.5 | 64 | 63 | 0.69 |
| | WHR | 0.605 | 69 | 58 | 0.70 |
| | BMI (kg/m$^2$) | 29.60 | 61 | 58 | 0.66 |

*WC* waist circumference, *WHR* waist-to-height ratio values according to different races, therefore, appear to be necessary.

Moreover, an increased risk of OSAS was determined in the event of a waist-to-height ratio of > 0.595 in women (sensitivity 78%, specificity 78%) and > 0.575 in men (sensitivity 76%, specificity 67%). Based on our further analysis from the point of severe OSAS, waist circumference values greater than 104.5 cm in women and 106.5 cm in men, waist-to-height ratio over 0.635 in women and 0.605 in men, and BMI higher than 29.9 in women and 29.6 in men were found to cause a risk for severe OSAS.

In this study, our aim was to search whether OSAS is correlated with waist-to-height ratio. Banhiran et al. found that among snoring male individuals, waist-to-height ratio ≥ 0.55 was a good predictor for moderate to severe OSAS [11]. Our literature search did not point out any studies attempting to set a waist-to-height ratio cutoff value for OSAS. Although our results do not confer any superiority to waist-to-height ratio over waist circumference in predicting OSAS development, it has been reported as a better determinative of prognosis in cardiovascular diseases than BMI and waist circumference [16]. In our study, however, these measurements were not assessed in terms of OSAS prognosis. These parameters are easily measured and may prove an essential role in predicting the presence of OSAS.

Our study is primarily limited by the age difference between the OSAS group and the control group. As a result of the increased OSAS prevalence by age, the OSAS group had a higher average age than the control group. Our age-adjusted evaluation of anthropometric measurements suggests a possible use of them in predicting OSAS. OSAS is reported 2 to 3 times more common in men than in women. Our patient group, congruently, is predominantly composed of males.

The study was designed as a cross-sectional study. Correlation, if any, of waist circumference, waist-to-height ratio, and BMI with the presence and severity of OSAS was investigated, but not with OSAS prognosis. When it comes to the prognosis of cardiovascular diseases, waist-to-height ratio has been reported in some studies as a better determinative than BMI [17, 18]. Prospective studies to evaluate the role of anthropometric measurements in predicting metabolic disease development and mortality would probably shed a light on patient follow-up.

## Compliance with ethical standards

**Ethical approval** This study protocol was approved by the ethics committee of Mugla Sıtkı Kocman University.

**Informed consent** Because this was a retrospective study, formal consent was not required.

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

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## Comment

As obstructive sleep apnea presents a large public health problem, there has been an ongoing search towards simpler measures to screen patients that may have obstructive sleep apnea (1-3). This study is an important addition to identify such a tool.

While neck circumference is established for its correlation to presence and severity of sleep apnea (4, 5), other measures of central obesity such as the waist circumference and waist-to-height ratio are noted for their correlation to cardio metabolic and mortality risk (6, 7). Some studies correlate waist circumference to neck circumference (8). Existing studies do not report correlation between waist-to-height ratio and OSA in adults although this was noted in a pediatric study in 2015 by DeSousa et al (9).

In this study Dr Unal et al aimed to investigate the correlation of waist-to-height ratio, with the presence and severity of obstructive sleep apnea syndrome and to compare its use with other indicators of central adiposity such as waist circumference and BMI. They also aimed to determine OSAS related cutoff values in patient's between Jan 2014 and Dec 2016 in the inpatient setting at their Sleep Lab.

The need for this information is vital and interesting as these measurements may help screen patients with obstructive sleep apnea there by selecting candidates for further testing. In addition, as screening anthropometric measures are bound to have racial and gender differences it is important to find "cutoff points" for different populations (10).

The study found that as expected, in patients with OSAS the waist-to-height ratio, waist circumference, and BMI were higher compared to the control group. The AHI scores correlated with all 3 parameters, but the highest correlation was noted for the waist circumference. This was also noted on a prior study by Davidson and Patel (11) and likely represents the results of pattern of fat distribution—increased fat deposition in the center as opposed to the periphery may result in decreased size of the upper airway secondary to mass effect of the abdomen fat on the chest wall and tracheal traction (12). Interestingly, correlation was much stronger in the female population. As is well known, women have more body fat but men have a relatively more central distribution of fat (13, 14). This may suggest that in women if there was increase in waist size, it likely represented a significant increase in adiposity. It is noteworthy that majority of the patient's in this study had moderate to severe OSA—75%.

Based on the area under the curve analysis, cutoff values were defined for men and women for waist circumference, waist-to-height ratio and the BMI, both for obstructive sleep apnea and severe obstructive sleep apnea.

As is to be expected, there was an age difference between control group and the group with obstructive sleep apnea.

In conclusion, for the waist-to-height circumference, in addition to previous knowledge of its ability to identify patient's at risk for cardio metabolic disease and mortality, the current study adds to its use to predict the presence and severity of obstructive sleep apnea.

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