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# Correlation Between Body-Shape Index, Body-Roundness Index, Body-Mass Index, and Apnea-Hypopnea Index in Patients with Obstructive Sleep Apnea Syndrome

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**Background:** This study aimed to evaluate the potential of recently developed anthropometric measures, A Body Shape Index (ABSI) and Body Roundness Index (BRI), in the diagnosis of Obstructive Sleep Apnea Syndrome (OSAS), to compare them with traditional indices (BMI) and to analyze them by gender.

**Methods:** The medical records of 400 patients who were admitted to our sleep clinic were retrospectively reviewed. Demographic data, obesity status, Apnea-Hypopnea Index (AHI), Oxygen Desaturation Index (ODI), and anthropometric measurements of all cases were obtained from their files. ABSI, BRI, and traditional indices were calculated according to appropriate formulas. Individuals were grouped according to AHI severity as follows: AHI <5: control; 5≤ AHI <15: mild; 15≤ AHI <30: moderate; and AHI ≥ 30: severe OSAS. Anthropometric indices were evaluated comparatively according to OSAS status and gender.

**Results:** Of the 400 participants included in the study, 58% were male (45.61±12.2 years) and 42% were female (49.01±12.3 years). The prevalence of OSAS was 75% (n=300). The degree of obesity in mild and severe OSAS patients varied significantly by gender (p=0.001, p=0.006). Among the new indices, BRI revealed a meaningful difference (p<0.001) between control and OSAS patients in both genders, while ABSI was not significant (male/female, p=0.719/p=0.848). BRI was significantly associated with OSAS (BRI-AHI, r=0.35; BRI-ODI, r=0.30). The diagnostic performance of BRI in OSAS patients was good (AUC 0.690 in men and AUC 0.650 in women). Nonetheless, it was not higher than BMI (AUC male/female, 0.693/0.712). ABSI did not perform adequately in the evaluation of OSAS.

**Conclusion:** BRI, a new anthropometric metric, has been found to be a useful index for the diagnosis of OSAS in both sexes. However, it was not superior to BMI. BRI showed a diagnostic performance similar to BMI in men, while in women, it was slightly lower than BMI but within an acceptable range. ABSI did not provide meaningful diagnostic value.

**Keywords:** apnea-hypopnea index, body mass index, body roundness index, obesity, obstructive sleep apnea syndrome

## Introduction

Obstructive sleep apnea syndrome is the most frequently diagnosed sleep disorder worldwide. It is a syndrome described as recurrent complete or partial obstruction of the upper airways during sleep, characterized by episodes of desaturation and arousal.[1,2] OSAS mainly causes adverse health consequences, such as increased daytime sleepiness, cardiovascular impairment, and increased morbidity and mortality, at great economic costs to health systems.[3,4]

Obesity is one of the most commonly observed major risk factors in OSAS. Overweight and obesity are among the major causes of global mortality and increasing world health problems.[5] The prevalence of OSAS is increasing in Western societies with the obesity epidemic.[6] Obesity increases the adipose tissue around the neck and especially around the pharynx, narrowing the upper respiratory tract and increasing the tendency of upper respiratory tract closure.[7]



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Given the magnitude of the problem, there is a need to predict or diagnose OSAS and it is important to develop simple, reliable, cost-effective methods to do so. Using anthropometric variables related to obesity is one option. The proportion of adipose tissue in the body has been related to obstructive respiratory events. Obesity increases the likelihood of developing many disorders, such as cardiovascular diseases, metabolic syndrome, diabetes, and musculoskeletal disorders.[8] BMI is considered the main classifier for obesity. Individuals with a BMI of 25 or more are classified as overweight, while those with a BMI of 30 or more are classified as obese.[5,9]

Polysomnography (PSG) is recognized as the gold standard diagnostic method for the detection of OSAS. However, because PSG is very expensive, time-consuming, necessitates a specialized team, and there are not enough laboratories, it is important to determine the obesity parameters that increase the likelihood of OSAS.[10,11] Currently, anthropometric measurements such as BMI and Waist Circumference (WC) are used in the evaluation of overweight and obesity. The BMI is a measure of general adiposity; however, it does not provide information regarding body fat distribution. By contrast, the WC is a reliable predictor of abdominal adipose tissue, though this is contingent on body size. Furthermore, anthropometric parameters are known to vary according to race and ethnicity and have been shown not to always give optimal results.[12,13] For these reasons, the need to combine traditional measures or to design better body indices has been identified.[14,15] Two new body indices have been defined in recent years, the ABSI (A Body Shape Index) and the BRI (Body Roundness Index).[16] ABSI has been associated with increased abdominal fat tissue and has been suggested to be an important major risk factor for early mortality. BRI has been described as an indicator of body fat and visceral adipose tissue and has also been associated with metabolic syndrome and cardiovascular risk.[17–19]

The purpose of this present study was to investigate the correlation of the new body indexes BRI and ABSI with AHI and to determine whether they are better than traditional indexes such as BMI in determining the diagnosis and severity of OSAS, and to reveal the differences according to gender.

## Materials and Methods

### Study Design and Study Population

This study was designed as a retrospective study, including patients who underwent polysomnography in our sleep laboratory between February 2017 and January 2018 with a prediagnosis of obstructive sleep apnea. The current study protocol was approved by S.B University Konya Training and Research Hospital, Medical Speciality Education Board on 01.02.2018 with Ethics Committee Approval No: 12–09 and Decision No: 48929119/ 774. Written informed ethical consent was obtained from all participants included in this research study.

A total of 1115 patients who underwent PSG were retrospectively screened, and 715 patients were excluded due to the following exclusion criteria: Incomplete PSG or Inadequate Sleep, Decompensated Clinical Comorbidities, Craniofacial Disorders, Incomplete Anthropometric Measurements, and Pregnancy. As a result, 400 patients who met our criteria were included in this study (Figure 1). Demographic characteristics, anthropometric measurements, and PSG records were obtained from patients' medical files. New and traditional anthropometric indices (ABSI, BRI, BMI, waist/hip ratio (WHR)) were calculated according to appropriate formulas. ESS scores of the patients were also recorded. An Epworth score above 10 was considered significant.

### Anthropometric Measurements

Anthropometric parameters included height, weight, waist circumference (WC), hip circumference (HC), and neck circumference (NC). The weight of all patients was measured in kilograms using standard clinical scales while wearing only room clothes and no shoes. Height was measured in metres using a standard stadiometer. Patients' circumference was measured in centimeters with a 0.6 cm wide, non-stretchable tape measure. NC was measured at the level of the upper edge of the cricothyroid membrane. WC was calculated from the narrowest part of the distance between the xiphoid process and the umbilicus in the horizontal position. Hip circumference was measured as the widest diameter in a horizontal plane on the trochanters, with the legs 20–30 cm apart.[20] Traditional and new anthropometric indices were calculated using standard and recommended formulas:

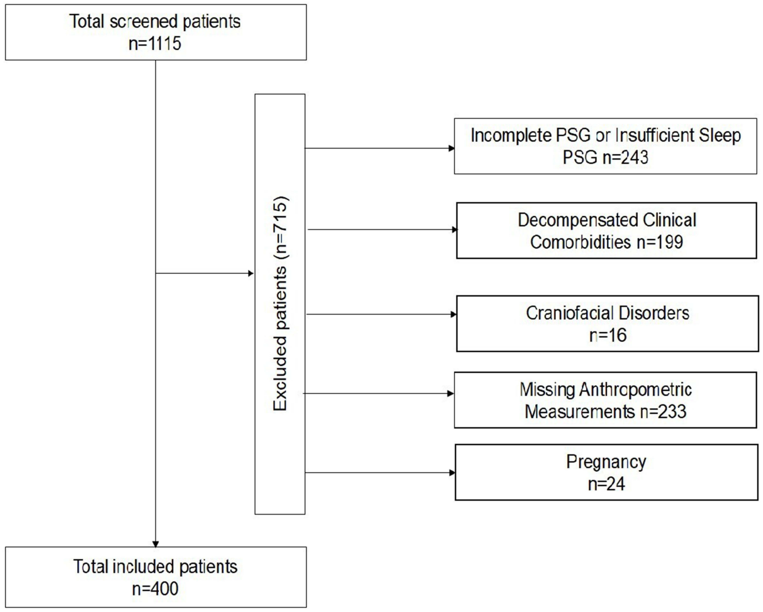


**Figure 1** Flow diagram of patient selection.

ABSI was calculated by including anthropometric parameters such as height (m), BMI (kg/m²), and WC (m) according to the formulae established by Krakauer et al: ABSI = WC / (BMI $^{(2/3)}$) x height$^{(1/2)}$)).[16] BRI was determined using height(m) and WC(m) and calculated using the formula proposed by Thomas et al. Initially, the eccentricity (€) of the body was calculated according to the following formula: Eccentricity (€ =√ (1-(WC/(2π)) ² / (0.5 × height) ²). Eccentricity is a dimensionless value that measures the degree of circularity of an ellipse, ranging from zero to one. BRI was then recalculated according to the following formula: BRI = 364.2- (365.5 × €).[18] Low BRI levels are associated with thinner persons, whereas high levels are associated with overweight persons. BMI was based on weight (kg) and height (m) and calculated using the classic formulation: BMI = weight/height².[20] The Waist/Hip Ratio (WHR) is on the basis of waist circumference (cm) and hip circumference (cm) and is calculated using the formula WHR = WC/HC.[21]

## Obesity Classification

Obesity classification was based on body mass index (BMI): normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥30 kg/m²; Class I: 30.0–34.9 kg/m², Class II: 35.0–39.9 kg/m² and Class III-severely obese: ≥40.0 kg/m²). In this study, participants with Class I and II obesity were defined as the obese group, while participants with Class III obesity were classified as severely obese.[5]

## Polysomnography

Polysomnographic examinations of all patients were performed with a sleep device (ALICE 6 LDE Sleepwear, USA). Polysomnography involved electroencephalogram, electrooculogram, electromyogram and electrocardiogram. Patients were also connected to a nasal pressure sensor, oral and nasal airflow thermistor, abdominal and chest impedance bands, pulse oximeter, tracheal microphone, and body position sensor. Nasal airflow and pulse oximetry were used to evaluate blood oxygen saturation levels during the overnight period. Mean and minimum oxygen saturation levels were analyzed from data recorded during the night. Oxygen Desaturation Index (ODI) is defined as a decrease of 3% or more in oxygen saturation during sleep. Polysomnography measurements were evaluated according to the American Academy of Sleep Medicine (AASM) criteria. AHI, which represents the number of apnea and hypopnea episodes per hour of sleep, was used to assess disease severity. Apnea during sleep was defined as a decrease in the respiratory signal by ≥ 90% from baseline, with this signal loss lasting ≥10 seconds. Hypopnea was described as a ≥30% decrease in the respiratory signal compared to baseline, with this signal loss lasting ≥10 seconds and a ≥3% decrease in baseline oxygen saturation before the event or before the event ended with arousal.[22] OSAS was identified as an AHI of 5 or more per hour. Patients were classified in accordance with AHI values as simple snoring (AHI<5), mild OSAS (5≤AHI<15), moderate OSAS (15≤AHI<30), and severe OSAS (30≤AHI).[22]

## Statistical Analysis

The statistical analyses of the data collected in the study were carried out using the Statistical Package for the Social Sciences (SPSS) software program (IBM SPSS for Windows, ver.22). While the categorical variables are presented as frequency and percentage, numerical variables are described as mean and standard deviation. While the categorical variables are presented as frequency and percentage, numerical variables are described as mean and standard deviation. Independent *T*-test was employed for two-group comparisons. In the analyses of more than two groups, One-Way Analysis of Variance (ANOVA) was used to determine the differences between the groups. For continuous variables, Pearson correlation analysis was used to measure relationship levels. The chi-square test was also applied for categorical variables. Receiver operating characteristics (ROC) analysis was used to assess the diagnostic performance of anthropometric parameters. All statistical tests were repeated separately for males and females. Statistical significance level was considered as p<0.05.

# Results

Of the 400 participants, 168 (42%) were female (mean age 45.61±12.2) and 232 (58%) were male (mean age 49.01 ±12.3). Of all subjects, 300 (75%) were OSAS patients (male/female 177/123) and 100 (25%) were controls (male/female 55/45).

The distribution of obesity according to OSAS severity is given in Table 1. Of the 300 patients with OSAS, 278 (92.7%) were in the obese group. Among patients with severe OSAS, 99% were in the obesity group. The degree of obesity in mild and severe OSAS patients showed a significant difference according to gender (p=0.001, p=0.006) (Table 1). In both OSAS groups, severe obesity was higher in women, and overweight was higher in men.

Comparison of anthropometric measurements and other features of OSAS and the control groups in men and women is given in Table 2. Age was considerably greater in OSAS patients as compared to the control group in both males and females (p=0.000). Among the anthropometric parameters, Weight, WC, NC, HC, BMI and BRI were significantly

**Table 1** Obesity Degrees of Male and Female Subjects According to OSAS Severity

| | Normal Weight BMI<25 kg/m$^2$ | Overweight 25≤BMI<30 kg/m$^2$ | Obese 30≤BMI<40 kg/m$^2$ | Severely Obese 40≤BMI kg/m$^2$ | p* |
|---|---|---|---|---|---|
| AHI<5 (n=100) | | | | | |
| Total n (%) | 27 (27.0) | 37 (37.0) | 33(33.0) | 3 (3.0) | 0.158 |
| Male | 16 (16.0) | 23 (23.0) | 16 (16.0) | 0 (0.0) | |
| Female | 11 (11.0) | 14 (14.0) | 17 (17.0) | 3 (3.0) | |
| 5≤AHI<15 (n=100) | | | | | |
| Total n (%) | 11 (11.0) | 37 (37.0) | 45 (45.0) | 7 (7.0) | <0.001 |
| Male | 6 (6.0) | 28 (28.0) | 21 (21.0) | 0 (0.0) | |
| Female | 5 (5.0) | 9 (9.0) | 24 (24.0) | 7 (7.0) | |
| 15≤AHI<30 (n=99) | | | | | |
| Total n (%) | 10 (10.1) | 32 (32.3) | 51 (51.5) | 6 (6.1) | 0.101 |
| Male | 6 (6.1) | 25 (25.2) | 29 (29.3) | 2 (2.1) | |
| Female | 4 (4.0) | 7 (7.1) | 22 (22.2) | 4 (4.0) | |
| 30≤AHI (n=101) | | | | | |
| Total n (%) | 1(1.0) | 26 (25.7) | 56 (55.5) | 18 (17.8) | 0.006 |
| Male | 0 (0.0) | 20 (19.8) | 35 (34.7) | 5 (5.0) | |
| Female | 1 (0.0) | 6 (5.9) | 21 (20.8) | 13 (12.8) | |

**Note**: *Chi-square test was applied.

**Table 2** Comparison of Anthropometric Measurements and Other Characteristics in Control and OSAS Patients

| | Control Mean ± SD | OSAS Mean ± SD | p |
|---|---|---|---|
| AGE | | | |
| Total | 39.70±12.41 | 49.52±11.33 | <0.001 |
| Male | 39.81±13.12 | 47.42±11.37 | <0.001 |
| Female | 39.59±11.65 | 52.57±10.61 | <0.001 |
| HEIGHT | | | |
| Total | 1.68±0.10 | 1.69±0.10 | 0.020 |
| Male | 1.75±0.07 | 1.73±0.07 | 0.068 |
| Female | 1.59±0.06 | 1.62±0.06 | 0.049 |
| WEIGHT | | | |
| Total | 80.75±16.89 | 91.36±15.30 | <0.001 |
| Male | 85.51±16.70 | 92.59±15.10 | <0.001 |
| Female | 75.06±15.45 | 89.60±15.48 | <0.001 |
| WC | | | |
| Total | 103.36±14.13 | 111.69±11.56 | <0.001 |
| Male | 104.35±11.61 | 111.02±11.28 | <0.001 |
| Female | 102.22±16.73 | 112.66±11.93 | <0.001 |
| NC | | | |
| Total | 39.43±2.87 | 40.83±2.68 | <0.001 |
| Male | 40.67±2.63 | 41.58±2.59 | 0.024 |
| Female | 37.96 ±2.45 | 39.74±2.44 | 0.000 |
| HC | | | |
| Total | 107.03±13.75 | 112.57±12.56 | <0.001 |
| Male | 104.31±11.81 | 109.17±10.62 | 0.004 |
| Female | 110.28±15.25 | 117.51±13.53 | 0.002 |
| BMI | | | |
| Total | 27.48±5.15 | 32.17±5.46 | <0.001 |
| Male | 27.66±4.28 | 30.79±4.33 | <0.001 |
| Female | 26.47±5.92 | 34.16±6.28 | <0.001 |
| BRI | | | |
| Total | 5.06±2.17 | 7.07±1.96 | <0.001 |
| Male | 5.41±1.49 | 6.49±1.64 | <0.001 |
| Female | 6.62±2.79 | 7.90±2.05 | <0.001 |
| ABSI | | | |
| Total | 0.09±0.01 | 0.08±0.01 | 0.600 |
| Male | 0.09±0.01 | 0.08±0.01 | 0.719 |
| Female | 0.08±0.01 | 0.08±0.01 | 0.848 |
| WHR | | | |
| Total | 0.97±0.08 | 0.99±0.07 | 0.001 |
| Male | 1.00±0.17 | 1.03±0.07 | 0.073 |
| Female | 0.94±0.08 | 0.95±0.11 | 0.043 |
| ODI | | | |
| Total | 1.35±1.17 | 26.33±26.02 | <0.001 |
| Male | 1.27±1.85 | 31.99±27.57 | <0.001 |
| Female | 1.44±1.26 | 24.01±21.47 | <0.001 |
| AHI | | | |
| Total | 1.35±1.17 | 26.33±26.02 | <0.001 |
| Male | 2.30±1.85 | 31.99±28.62 | <0.001 |
| Female | 3.60±12.69 | 28.54±23.37 | <0.001 |

**Abbreviations**: ABSI, A body Shape index; BRI, Body Roundness Index; BMI, Body Mass Index; NC, Neck Circumference; WC, Waist Circumference; HC, Hip Circumference; WHR, Waist-to-Hip Ratio; ODI, Oxygen Desaturation Index; AHI, Apnea-Hypopnea Index.


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different between the groups in both sexes. Height and WHR were significantly different in women but not in men. ABSI showed no significant difference between the groups in both sexes.

Anthropometric measurements and clinical characteristics according to the degree of OSAS in male and female subjects are given in Table 3. In men, Weight (p= 0.013), WC (p= 0.045), BMI (p= 0.001), and BRI (p= 0.022) were statistically significantly different between Mild-severe OSAS groups. BMI (p= 0.001) and BRI (p= 0.022) were statistically different between moderate and severe OSAS groups. There was no statistically significant difference in anthropometric measurements between mild and moderate OSAS patients (p> 0.05). Anthropometric measurements in female patients with OSAS did not show statistically significant differences between OSAS severity groups (p>0.05). On the other hand, age, ODI, and AHI were statistically significant in the mild-moderate OSAS (p<0.001), moderate-severe OSAS (p<0.001), and mild-severe OSAS (p<0.001) groups in both men and women (Table 3).

The correlations between anthropometric measurements and AHI and ODI in men and women are given in Table 4. The correlations between the studied anthropometric parameters and AHI values were analyzed separately for men and

**Table 3** Anthropometric Measurements and Clinical Characteristics According to OSAS Severity in Male and Female

| | MILD OSAS Mean ± SD | MODERATE OSAS Mean±SD | SEVERE OSAS Mean±SD | p |
|---|---|---|---|---|
| AGE | | | | |
| Total | 46.11±11.09[a] | 48.84±10.87[b] | 53.62±10.85[c] | <0.001 |
| Male | 44.36±11.69[a] | 46.19±10.51[b] | 51.50±10.92[c] | 0.002 |
| Female | 48.24±10.03 | 53.27± 10.09 | 56.36±10.31[c] | 0.002 |
| HEIGHT | | | | |
| Total | 1.68±0.08 | 1.70 ±0.09 | 1.68±0.01 | 0.114 |
| Male | 1.72±0.06 | 1.74±0.08 | 1.72±0.06 | 0.231 |
| Female | 1.62±0.07 | 1.63±0.06 | 1.61±0.06 | 0.541 |
| WEIGHT | | | | |
| Total | 84.4±12.79[a] | 90.33±15.79[b] | 95.30±16.39[c] | 0.004 |
| Male | 88.49±10.99 | 92.24±15.67 | 96.71±16.80[c] | 0.013 |
| Female | 88.35±14.82 | 87.13±25.0 | 92.49±14.0 | 0.275 |
| WC | | | | |
| Total | 110.43±11.54 | 110.05±10.99[b] | 114.56±10.99[c] | 0.009 |
| Male | 108.78±10.47 | 110.27±11.55 | 113.83±1132[c] | 0.045 |
| Female | 112.46±12.56 | 109.67±12.11 | 115.29±10.63 | 0.115 |
| NC | | | | |
| Total | 40.74±2.64 | 40.90±2.74 | 40.85±2.71 | 0.904 |
| Male | 41.81±2.27 | 41.58±2.66 | 41.36±2.81 | 0.432 |
| Female | 39.42±2.47 | 39.78±2.51 | 39.97±2.42 | 0.573 |
| HC | | | | |
| Total | 112.79±5.15 | 111.19±11.49 | 113.73±13.59 | 0.356 |
| Male | 108.36±9.20 | 108.50±9.76 | 110.61±12.55 | 0.836 |
| Female | 118.20±13.89 | 115.70±12.84 | 118.24±13.78 | 0.641 |
| BMI | | | | |
| Total | 31.48±5.46 | 31.18±5.17[b] | 33.82±5.41[c] | 0.001 |
| Male | 29.58±3.32 | 30.23±4.24[b] | 32.49± 4.74[c] | 0.001 |
| Female | 33.82±6.59 | 33.77±6.16 | 35.53±6.00 | 0.150 |
| BRI | | | | |
| Total | 6.98±2.14 | 6.67±1.86[b] | 7.44±1.78[c] | 0.006 |
| Male | 6.21±1.58 | 6.29±1.65[b] | 6.96±1.60[c] | 0.022 |
| Female | 7.93±2.35 | 7.30±2.01 | 8.34±1.72 | 0.087 |

(*Continued*)

**Table 3** (Continued).

| | MILD OSAS Mean ± SD | MODERATE OSAS Mean±SD | SEVERE OSAS Mean±SD | p |
|---|---|---|---|---|
| ABSI | | | | |
| Total | 0.09±0.007 | 0.08±0.006 | 0.08±0.006 | 0.566 |
| Male | 0.09±0.007 | 0.09±0.007 | 0.08±0.006 | 0.600 |
| Female | 0.08±0.008 | 0.08±0.006 | 0.08±0.006 | 0.853 |
| WHR | | | | |
| Total | 0.981±0.07 | 0.993±0.07 | 1.012±0.06[c] | 0.011 |
| Male | 1.004±0.06 | 1.016±0.06 | 1.031±0.05[c] | 0.070 |
| Female | 0.953±0.07 | 0.950±0.06 | 0.980±0.07 | 0.122 |
| ODI | | | | |
| Total | 7.29±3.51[a] | 17.60±5.40[b] | 54.01±27.92[c] | <0.001 |
| Male | 7.34±3.24[a] | 16.46±5.29[b] | 58.63±30.38[c] | <0.001 |
| Female | 7.23±7.23[a] | 19.49±19.49[b] | 45.96±45.96[c] | <0.001 |
| AHI | | | | |
| Total | 10.55±2.65[a] | 21.31±3.45[b] | 60.05±25.64[c] | <0.001 |
| Male | 10.42±2.75[a] | 21.22±3.26[b] | 62.88±26.90[c] | <0.001 |
| Female | 10.72±2.53[a] | 21.45±3.86[b] | 55.92±23.74[c] | 0.002 |

**Notes**: [a] Statistically significant difference between the mild and moderate groups. [b] Statistically significant difference between the moderate and severe groups. [c] Statistically significant difference between the mild and severe groups.

**Abbreviations**: ABSI, A body Shape index; BRI, Body Roundness Index; BMI, Body Mass Index; NC, Neck Circumference; WC, Waist Circumference; HC, Hip Circumference; WHR, Waist-to-Hip Ratio; ODI, Oxygen Desaturation Index; AHI, Apnea-Hypopnea Index.

**Table 4** Correlations of New and Traditional Anthropometric Indices with ODI and AHI in Both Genders

| | BRI | ABSI | BMI | WHR | WC | NC | HC |
|---|---|---|---|---|---|---|---|
| Male | | | | | | | |
| AHI | 0.316** | −0.042 | 0.371** | 0.137* | 0.291** | 0.030 | 0.227** |
| ODI | 0.303** | −0.051 | 0.382** | 0.145* | 0.307** | 0.060 | 0.233** |
| Female | | | | | | | |
| AHI | 0.225** | 0.002 | 0.265** | 0.199* | 0.278** | 0.244** | 0.173* |
| ODI | 0.303** | 0.010 | 0.327** | 0.182* | 0.350** | 0.316** | 0.258** |

**Notes**: *Correlation is significant at the 0.05 level (p<0.05). **Correlation is significant at the 0.001 level (p<0.001).

**Abbreviations**: ABSI, A Body Şhape Index; BRI, Body Roundness Index BMI, Body Mass Index; NC, Neck Circumference; WHR, Waist-to-Hip Ratio; WC, Waist Circumference; HC, Hip Circumference; AHI, Apnea-Hypopnea Index; ODI, Oxygen Desaturation Index.

women. The anthropometric parameters that showed significant correlation with AHI in the male population were BMI (r= 0.371), BRI (r= 0.316), WC (r= 0.291), HC (r= 0.227), and WHR (r= 0.137), respectively. In women, the order of the variables was different: WC (r= 0.278), BMI (r= 0.265), NC (r= 0.244), BRI (r= 0.225), and WHR (r= 0.199). In males, anthropometric parameters that showed a significant correlation with ODI were BMI (r= 0.382), WC (r= 0.307), BRI (r= 0.303), HC (r= 0.233), and WHR (r= 0.145), respectively. In females, the order of the variables was different: WC (r= 0.350), BMI (r= 0.327), neck circumference (r= 0.316), BRI (r= 0.303), HC (r= 0.258), and WHR (r= 0.182). Among the anthropometric parameters studied, the strongest correlation with ODI and AHI was seen between BMI in men and WC in women. However, BRI was also significantly correlated with both AHI and ODI. ABSI was not significantly correlated with ODI and AHI.

**Table 5** The Discriminatory Power of Anthropometric Measurements in the Diagnosis of OSAS in Male and Female Cases

| | Area | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| Male | | | | | |
| BMI | 0.693 | 0.042 | <0.001 | 0.608 | 0.775 |
| BRI | 0.692 | 0.041 | <0.001 | 0.611 | 0.771 |
| WC | 0.664 | 0.043 | <0.001 | 0.580 | 0.749 |
| HC | 0.641 | 0.047 | 0.002 | 0.550 | 0.733 |
| NC | 0.602 | 0.045 | 0.024 | 0.514 | 0.688 |
| WHR | 0.580 | 0.043 | 0.073 | 0.496 | 0.664 |
| ABSI | 0.513 | 0.046 | 0.766 | 0.424 | 0.603 |
| Female | | | | | |
| BMI | 0.712 | 0.044 | <0.001 | 0.626 | 0.799 |
| NC | 0.703 | 0.047 | <0.001 | 0.611 | 0.795 |
| WC | 0.686 | 0.051 | <0.001 | 0.587 | 0.786 |
| BRI | 0.650 | 0.052 | 0.003 | 0.548 | 0.752 |
| HC | 0.632 | 0.051 | 0.009 | 0.532 | 0.731 |
| WHR | 0.602 | 0.049 | 0.042 | 0.506 | 0.698 |
| ABSI | 0.482 | 0.056 | 0.713 | 0.371 | 0.592 |

**Abbreviations**: BMI, Body Mass Index; BRI, Body Roundness Index; NC, Neck Circumference; WHR, Waist-to-Hip Ratio; ABSI, A Body Shape Index; CI, Confidence Interval.

The results of ROC analysis to determine the diagnostic performance of anthropometric measurements in OSAS patients are given in Table 5. In men and women, BMI was found to be the most effective anthropometric parameter in the diagnosis of OSAS (Figure 2). BRI (AUC 0.691), one of the new anthropometric measures in men, showed high diagnostic performance similar to BMI (AUC 0.692). In women, BRI (AUC 0.650) also had adequate diagnostic performance, but BMI (AUC 0.712) was superior. NC (AUC 0.703) also had high diagnostic performance in women. In both sexes, ABSI (AUC 0.513 in men, AUC 0.482 in women) did not show adequate diagnostic performance.

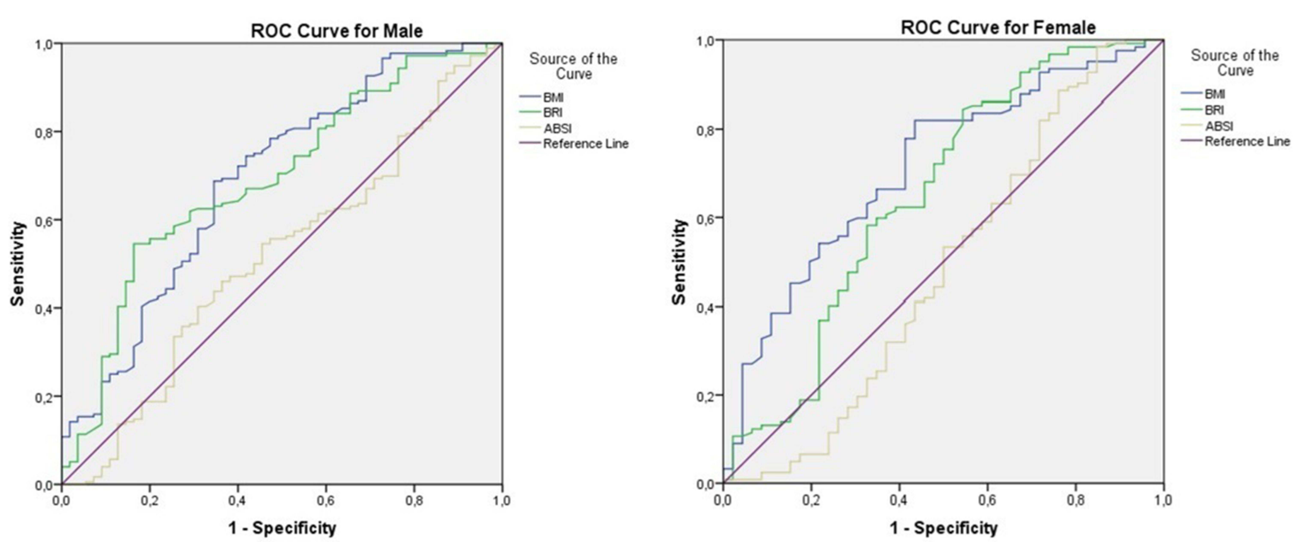


**Figure 2** Discriminative power of anthropometric indices by ROC analysis in male and female subjects.

## Discussion

This study mainly investigated the effectiveness of the novel anthropometric indexes BRI and ABSI in the evaluation of OSAS and compared these measurements with traditional measurements. It also revealed the differences in the indices according to gender. Our results revealed that anthropometric parameters associated with obesity are closely linked with the development of OSAS and that there are differences in parameters showing this relationship according to gender. The new index BRI was found to have diagnostic performance similar to BMI in men and lower than BMI in women, but within an acceptable range. However, it was revealed that ABSI, one of the new indices, did not show an adequate performance in the evaluation of OSAS.

In recent years, with a better understanding of the physiopathology, risk factors, and complications, OSAS has been shown to be an important cause of mortality and morbidity.[23] The most important risk factors observed in OSAS are male gender, advanced age, obesity, upper airway anatomical disorders, and genetic predisposition.[10] The high prevalence of OSAS has been observed in middle-aged male patients. In our study, age was statistically significantly higher in both males and females between normal and OSAS patients, and OSAS severity increased with increasing age. The average age of our OSAS patients was 47.42 years in men and 52.57 years in women, consistent with the literature.

Obesity has a very important role in the pathophysiology of OSAS, and a strong dose-response relationship has been shown between obesity and OSAS.[20,24] It is accepted that central obesity improves the susceptibility to OSAS by influencing upper airway opening and respiratory pattern with fat deposition around the upper airway and abdominal region.[25] This mechanism may explain the higher prevalence of abdominal obesity in individuals with OSAS. In a study, it was reported that 2/3 of middle-aged OSAS patients were obese and the majority had central obesity.[26] Lopez et al found that the prevalence of OSAS was over 70% in severely obese patients and over 40% in obese patients.[27] Ayık et al reported that 93.8% of OSAS cases had obesity and overweight.[28]

In our present study population, the high prevalence of obesity in patients with OSAS was similarly high (92.7%); 89% of subjects with mild and moderate OSAS and 99% of subjects with severe OSAS were in the overweight and obese (BMI>29) group. Our results support the significant effect of being obese on the progression and severity of OSAS, which is widely recognized in the literature.

Gender-related fat distribution differences are thought to have a significant role in the occurrence of OSAS. It has also been reported that fat accumulation due to androgenic fat distribution, which is more prominent around the upper airway in the male gender, significantly increases the risk of OSAS. There are different opinions about OSAS development and adiposity differences in women. Although it is known that women are more prone to gynoid adiposity and general adiposity, it is suggested that postmenopausal hormonal changes shift the fat distribution to androgenic type and this increases the risk of OSAS.[29] It is reported that the gender difference in OSAS is high, and the man/woman ratio ranges from 1/2 to 1/4. However, it is also stated that the difference may not be so high and that women are largely underdiagnosed.[30] In our study cohort, the prevalence of OSAS was found to be 42% in women and 58% in men, and a very high difference was not found between the sexes compared to most studies. In addition, the degree of obesity in mild and severe OSAS patients differed significantly according to gender in our study. While being overweight was more common in men, severe obesity was found to be more prominent in women.

BMI, WC, NC, and WHR are traditional anthropometric measurements that are widely recognized in the assessment of obesity, which has an important role in the etiology of OSAS. The severity of OSAS is associated with fat accumulation, especially in the abdominal region, d and it has been reported that an increase in waist circumference significantly increases the risk of OSAS. A WC of 100 cm in males and 95 cm or more in females has been reported to carry a significant risk for OSAS and chronic diseases.[31] Soylu et al reported a WC of 105 cm in males and 101 cm or more in females as a risk for OSAS development.[32] There are also studies reporting different values depending on genetic background and regional factors. In our study, the waist circumference of OSAS patients was 111.02±11.28 cm in men and 112.66±11.93 cm in women. In our study cohort, waist circumference in both sexes was well above the risk limits reported in the literature.

WHR is a measurement tool designed to identify android (visceral) and gynoid (peripheral) obesity. Of these two types of obesity, visceral obesity is highly correlated with OSAS.[33] A WHR of more than 0.90 in males and 0.85 in females has been reported as an indicator of android obesity and obesity-related chronic disease risk.[34] In our study, the

WHR was 1.03±0.07 in males and 0.95±0.11 in females with OSAS. And WHR ratios in both sexes were above the risk limits in the literature. This indicated that android-visceral obesity was prominent in both sexes. Approximately half of our female patients were over 50 years of age. This may suggest that the high WHR in women is affected by age and hormonal factors.

A strong relationship between central obesity, neck diameter and OSAS has been reported. Neck circumference and central obesity gain importance, especially in patients with normal BMI.[35] Dancey et al emphasized that neck circumference is more important than BMI in determining AHI.[36] Patel et al considered a neck circumference of 43 cm (17 inch) in males and 38 cm (15 inch) in females to be very important.[37] Soylu et al considered an NC of 40 cm for males and 36 cm or above for females to be risky for OSAS in their study population.[32] In our study, neck circumference was significantly higher in patients with OSA in both sexes compared to the control group. While it was 37.96±2.45 cm in women and 40.67±2.63 cm in men in the control group, it was 39.74±2.44 cm in women and 41.58±2.59 cm in men with OSAS. This shows that central obesity and android obesity types were dominant in both sexes. Especially the increase in neck circumference in women with OSAS was significantly higher and positively correlated with AHI and ODI.

In recent years, two novel anthropometric body indexes, ABSI and BRI, have been defined to potentially overcome the restrictions of conventional measurements in the assessment of obesity and general health risks.[16,18] These indices aim to better predict health risks by emphasizing factors such as body shape, fat distribution, and abdominal obesity.[38]

ABSI is a new anthropometric index developed by Krakauer et al based on WC corrected for height and weight. They reported that this new index can predict general health status and risk of premature death better than traditional indices.[16] In some studies, it has been suggested as a useful method in the assessment of metabolic syndrome and the risks of chronic diseases.[39,40] However, Maessen et al reported that ABSI was insufficient to distinguish individuals with cardiovascular risk factors or disease from others.[41] In another study, it was suggested that BRI may be a better predictor of OSA risk compared to other anthropometric measurements, especially in the early detection of the high-risk OSA population.[42] In our present study, ABSI did not show a statistically significant difference between control and OSAS subjects in male and female patients (0.08±0.01 in males and 0.08±0.01 in females). We also found no meaningful relationship between ABSI and AHI (ABSI-AHI, male/female r=−0.042/0.002). We speculated that unmeasured confounders (eg, muscle mass, ethnicity, dietary habits) may play a role in the poor performance of the ABSI.

BRI is also another index developed by Thomas et al to evaluate body shape and fat composition and to estimate health risks.[18] It aims to estimate both visceral adiposity and body fat composition based on measurements such as waist circumference and height.[41] Some studies in recent years have compared Body Mass Index (BMI) with BRI in assessing health risks associated with body fat distribution. They reported that BRI is an effective metric in assessing the risks of hypertension, diabetes and prediabetes and in predicting mortality risk. They reported BRI as a potentially useful clinical predictor of metabolic syndrome.[43] However, in a research conducted by Maessen et al, BRI was identified as a useful index in determining cardiovascular disease status, but its superiority to anthropometric measurements such as BMI and WC could not be demonstrated.[41] In our study, we demonstrated the potential of BRI in the evaluation of OSAS. BRI was observed to be statistically significantly different between normal and OSAS subjects in both males and females (male/female p=0.005/0.004). A highly statistically highly significant relationship was also shown between BRI and AHI (male/female r= 0.316/0.225).

According to the ROC analysis to identify and compare the diagnostic performance of new and traditional anthropometric measurements in the diagnosis of OSAS, ABSI was not meaningful in both genders (AUC 0.513 in men and AUC 0.482 in women). The new anthropometric measure BRI (AUC 0.691) had a high diagnostic performance in men but was similar to BMI (AUC 0.692). In women, BRI (AUC 0.650) had adequate diagnostic performance but was superior to BMI (AUC 0.712, cutoff value). Although our results demonstrate the potential use of BRI in the evaluation of OSAS, we did not detect its superiority over BMI.

The strength of our study was that PSG was performed in all patients. However, this study had several limitations. First, due to the study design, medical data were collected retrospectively. In addition, the lack of stratification by age groups limited the ability to assess the effect of age-related anthropometric differences. Considering that anthropometric parameters may be affected by factors such as ethnicity, genetic background, and lifestyle, it can be said that the single-center study constituted another limitation in terms of generalizability.

## Conclusion

In conclusion, in this study, new and traditional anthropometric measurements that can be used in OSAS patients were evaluated and compared in men and women. The data obtained in our study showed that BRI, a new anthropometric index, is associated with OSAS and has a significant diagnostic performance in the diagnosis of OSAS. However, it was not found to be superior to BMI. The diagnostic performance of BRI was similar to BMI in men and lower than BMI in women, but within acceptable limits. ABSI was not a significant anthropometric measurement in the direct assessment of OSAS. These results showed that although BRI is a useful index in the diagnosis of OSAS, BMI remains a reliable predictor. Further studies using prospective cohorts, including age differences and regional and ethnic factors, are needed to determine the causal link between OSAS and the new anthropometric parameters and to determine their efficacy in clinical practice.

## Data Sharing Statement

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

## Ethical Considerations

The current study protocol was approved by S.B. University Konya Training and Research Hospital, Medical Speciality Education Board on 01.02.2018 with Ethics Committee Approval No: 12-09 and Decision No: 48929119/ 774. This study was conducted following the 1975 helsinki Declaration, as revised in 2008, and later amendments or comparable ethical standards. All adult participants provided informed consent.

## Informed Consent

Written informed consent was obtained from all participants.

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## Disclosure

The authors declare that they have no competing interests in this work.

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