

Assessment of obesity indices and disease severity in male patients with obstructive sleep apnea: a cross-sectional study

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Received: 3 March 2024

Revised: 17 April 2024

Accepted: 24 April 2024

Published: 24 December 2024

Journal of The Arab Society for Medical Research 2024, 19:101–108

Background/aim

Obstructive sleep apnea (OSA) is associated with multiple chronic conditions and increased risks of complications and mortality. The relationship between OSA and obesity is complex but increased body fat is widely recognized as a major risk factor for OSA. This work aims to determine the cut-off values of the body mass index (BMI), waist to hip ratio (WHR), neck circumference (NC) that can be used to predict the occurrence of OSA and its severity.

Patients and methods

This observational cross-sectional study included 241 Egyptian male patients, complaining from symptoms of OSA. The patients were subjected to measurements of obesity indices and underwent polysomnography to confirm the diagnosis of OSA according to the recommended guidelines for the manual scoring of respiratory events.

Results

The present study exhibited a significant association between BMI, WHR and NC with different polysomnographic parameters. BMI, NC, and WHR were the most significant predictors of OSA ($P < 0.05$). Cutoff values reported 34.35 kg/m² for BMI with 73.2% sensitivity and 69.4% specificity, while for NC reported 42.5 cm with 68.3% sensitivity and 75.5% specificity, and for WHR exhibited 1.0259 cm, with 59.9% sensitivity and 65.3% specificity. The severity of OSA in male sex was associated with older age, increased BMI, NC, WHR. The severity of OSA was also associated with decreased O₂ saturation and higher Desaturation index, Arousal index, and snoring index.

Conclusion

Increased BMI, NC, and WHR were the most significant predictors of OSA and correlated with the severity of the disease in male patients.

Keywords:

BMI, neck circumference, obesity, obstructive sleep apnea, waist to hip ratio

J Arab Soc Med Res 19:101–108

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1687-4293

Introduction

Obstructive sleep apnea (OSA) affects around 34 and 17% of men and women, respectively in western populations [1] while in Egypt, a recent study reported that 80% of the patients referred to sleep clinics were diagnosed with OSA [2]. The condition is highly correlated to obesity and is associated with many chronic diseases, and increased risks of death [3].

A four-year longitudinal study of obese adults demonstrated that the weight change is directly correlated to the severity of OSA [4]. However, in Egypt, where obesity rates are high (37% in men and 51% in women), data regarding the extent of the disease is still limited [5].

Body Mass Index (BMI), often used to assess body weight, is a weight-for-height measure and hence not suitable to identify the site of fat distribution. In contrast, waist-to-hip ratio (WHR) and neck circumference (NC) are considered practical

measures to assess truncal obesity and upper body fat distribution that mostly cause repetitive upper airway collapsibility in OSA [6,7].

The link between the severity of OSA and obesity indices has been well established in western populations [6–11] but in contrast, to our knowledge, scarcely outlined in Egypt [12]. In this study, we sought to assess the cut-off values of the obesity indices namely the BMI, WHR, and NC that can be used to evaluate and predict the severity of OSA.

Patients and methods

Patients

This cross-sectional observational study was conducted on 241 Egyptian male patients older than 18 years,

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visiting, or referred to the Outpatient Clinics of Chest Diseases Department, Kasr Alainy Hospital, Faculty of Medicine, Cairo University and Outpatient Clinics of Chest Diseases units and Complementary Medicine Department, Medical and Scientific Centre of Excellence, National Research Centre, Cairo, Egypt. All patients were complaining from any of these symptoms: snoring, difficulty breathing and/or choking sensation during sleep, and sleep deprivation with or without daytime sleepiness.

Study design

The patients included were categorized based on their total Apnea Hypopnea Index (AHI)/h calculated as the total number of apneas and hypopneas events divided by the total hours of sleep time (AHI/total) [13]. Patients with AHI/Total less than 5 were considered as the control group ($n=48$) and patients groups diagnosed with OSA were divided into mild (AHI/Total 5–15) ($n=25$), moderate (AHI/total 15–30) ($n=25$) and severe (AHI/total > 30) ($n=143$) OSA groups. In contrast, we excluded patients known to have comorbid cardiac, respiratory, or neurological chronic diseases, or known of alcohol, or drug abuse.

Ethical approval

This study was conducted with respect to the guidelines laid down in the Declaration of Helsinki and was reviewed and approved by the Ethical Committee of the National Research Centre, Cairo, Egypt, with approval number: 01431223, a written informed consent was provided by each participant before their inclusion in the study.

Methods

Anthropometric measurements

In the current work, we recorded the demographic and anthropometric data including weight, height, BMI in kg/m^2 , NC, and WHR. A Seca scale and a Seca 225 stadiometer (Seca, Hamburg, Germany) were used when measuring weight and height, respectively. Body weight was determined to the nearest 0.01 kg with the participant wearing minimal clothes and with no shoes. Height was measured to the nearest 0.1 cm. BMI [weight (in kg) divided by height (in m^2)], was calculated and obesity was defined according to the classification of the WHO [14]. NC was measured at the level of the cricothyroid membrane, waist circumference was measured halfway, between the inferior rib margin and the anterior superior iliac spine, and hip circumference was measured at the maximum circumference of the buttocks, in an erect position while the patient's feet placed together [15].

Polysomnography study

The diagnosis of OSA was confirmed after a full polysomnography study, using Philips Respironics Inc., Murrysville, PA, (USA), and analyzed according to the American Academy of Sleep Medicine–recommended guidelines for the manual scoring and interpretation of respiratory events [16].

Sample size

Using the PASS 11th release and information from a previous study [11], a minimal sample size of 118 cases was required to achieve 80% power in detecting a difference between an assumed area under the curve (AUC) for WHR in predicting OSA.

Statistical analysis

All data were coded and entered using the statistical package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Data was summarized using mean $\pm$ SD, Comparisons between groups were done using analysis of variance (ANOVA) with multiple comparisons *post hoc* test in normally distributed quantitative variables. Correlations between quantitative variables were done using the Pearman correlation coefficient. Receiver operating characteristic curve was constructed with area under curve analysis performed to detect best cutoff value of significant parameters for detection of severe OSA. *P* values less than 0.05 were considered statistically significant.

Results

In the current study, 241 male patients were included. The Demographic and anthropometric data of all patients are represented in Table 1: age (52.01 ± 14.96 years), weight (102.15 ± 22.48 kg), height (168.40 ± 9.79 cm), BMI (36.03 ± 7.71 kg/m^2), NC (42.16 ± 4.39 cm), waist circumference of (117.66 ± 18.04 cm), hip circumference (116.48 ± 16.43 cm), and WHR (1.01 ± 0.08).

The data represented in Table 2 illustrates the sleep study results (mean $\pm$ SD) with different sleep stage

Table 1 Demographic and anthropometric data of male patients included in the study

Age (years)	52.01 $\pm$ 14.96
Anthropometric data	
Weight (kg)	102.15 $\pm$ 22.48
Height (cm)	168.40 $\pm$ 9.79
BMI (kg/m^2)	36.03 $\pm$ 7.71
Neck circumference (cm)	42.16 $\pm$ 4.39
Waist circumference(cm)	117.66 $\pm$ 18.04
Hip circumference(cm)	116.48 $\pm$ 16.43
Waist to Hip ratio	1.01 $\pm$ 0.08

All data are expressed as mean + SD, BMI: body mass index.

Table 2 Results of polysomnography of male patients included in the study

Parameters	Mean + SD
Recording duration (min)	360.60±61.12
TST (min)	278.08±72.27
TIB (min)	351.28±60.03
Sleep efficiency (%)	78.61±16.05
REM %	5.44±7.63
Stage N1%	19.84±13.63
Stage N2%	67.05±13.72
Stage N3%	8.05±9.08
Obstructive apneas	175.92±157.82
Hypopneas	47.05±60.50
AHI/Total	43.72±34.22
AHI/NREM	42.89±34.22
AHI/REM	38.17±30.50
Average HR (beat/min)	69.42±16.83
Average O ₂	92.74±3.88
Lowest O ₂	74.65±17.21
Desaturation Index	55.91±38.41
Arousal index	40.48±26.80
Snoring index	36.17±27.11

AHI, apnea hypopnea index; HR, heart rate; NREM, nonrapid eye movement; REM, rapid eye movement; TIB, time in bed; TST, total sleep time.

percentages of all patients: Total sleep time (278.08±72.27 min), Sleep efficiency (78.61±16.05%), Obstructive apneas (175.92±157.82), Hypopneas (47.05±60.50), AHI/Total (43.72±34.22), Average O₂ (92.74±3.88), Desaturation index (55.91±38.41) and Arousal index (40.48±26.80).

In the current work, based on the polysomnography findings, the control group consisted of 48 (19.9%) patients while those diagnosed with mild, moderate, and severe OSA were 25 (10.4%), 25 (10.4%), and 143 (59.3%), respectively. Their data represented in Table 3 exhibited a significant difference ($P<0.05$) regarding age distribution since patients with moderate and

severe AHI/total were significantly older when compared with control group and patients with mild OSA. Additionally, a significant difference was found ($P<0.05$) regarding BMI, NC, and WHR between the studied groups. Patients with severe AHI/total had significantly elevated BMI and larger NC in contrast to the control group and patients with mild OSA. Patients with severe disease also had significantly elevated WHR when compared with patients not diagnosed with OSA. Regarding sleep parameters, AHI/total was significantly different ($P<0.05$) between studied groups as patients with severe OSA showed a greater increase in the AHI/total in respect to other studied groups. A statistically significant difference ($P<0.05$) was also observed in other sleep parameters such as average and lowest O₂, desaturation index, arousal index, and snoring index.

The data shown in Table 4 describes the correlations found between the obesity indices and polysomnography results. The increase in BMI exhibited a statistically significant positive association ($P<0.05$) with the severity of AHI/total (Fig. 1), as well as with the desaturation index, arousal index, snoring index, and other sleep parameters. Inversely, the increase in BMI was significantly associated ($P<0.05$) with reduced REM %, average and lowest O₂ during sleep. Similarly, significant positive correlations ($P<0.05$) were observed between NC with the AHI/total (Fig. 2), and the desaturation Index, arousal index, and snoring index, while statistically significant negative correlations ($P<0.05$) existed between NC with each of REM%, N3%, average, and Lowest O₂. Regarding the WHR, statistically significant positive correlations ($P<0.05$) were found between the WHR with AHI/total (Fig. 3) as well as with the desaturation index and arousal index. In contrast, a

Table 3 Comparison between male patients diagnosed with obstructive sleep apnea and the control group regarding demographic and polysomnographic data

	Control	Mild OSA	Moderate OSA	Severe OSA
Age (years)	44.85±16.43 ^a	48.69±14.06 ^b	54.81±15.38 ^c	54.72±13.58 ^c
BMI (kg/m ²)	30.57±6.29 ^a	33.53±6.60 ^b	34.78±8.69 ^b	38.51±7.04 ^c
NC (cm)	38.11±4.07 ^a	40.68±4.22 ^b	41.84±4.99 ^b	43.85±3.31 ^c
Waist to Hip Ratio	0.96±0.09 ^a	1.01±0.06 ^b	1.00±0.08 ^b	1.03±0.06 ^c
AHI/Total	1.9±1.5 ^a	9.7±3 ^b	21.5±4.2 ^c	67.6±22.7 ^d
Average HR (beat/min)	71.15±11.08 ^a	71.81±21.39 ^a	69.26±12.86 ^b	68.77±17.51 ^b
Average O ₂	94.75±2.61 ^a	94.75±1.39 ^a	94.43±2.82 ^a	91.86±4.13 ^b
Lowest O ₂	86.50±4.03 ^a	83.50±22.83 ^b	82.86±12.04 ^b	70.27±16.08 ^c
Desaturation index	9.97±20.41 ^a	15.02±11.19 ^b	30.81±32.05 ^c	73.66±30.05 ^d
Arousal index	15.15±11.80 ^a	16.18±10.86 ^a	23.44±16.97 ^b	50.75±25.00 ^c
Snoring index	16.61±22.39 ^a	28.17±26.75 ^b	39.08±27.58 ^c	47.82±14.99 ^d

All Data are expressed as mean + SD. AHI/Total: apnea hypopnea index/total sleep time, BMI: body mass index, HR: heart rate, NC: neck circumference. All data with different letters (a, b, c, d) in the same row are significantly different at P values less than 0.05 using ANOVA test.

Table 4 Spearman correlations between body mass index, neck circumference, and waist to hip ratio with results of polysomnography in all male patients

	BMI	NC	WHR
Sleep efficiency			
r	-0.013-	0.059	-0.012
P value	0.875	0.463	0.882
REM %			
r	-0.333-	-0.206-	-0.071
P value	< 0.001*	0.009*	0.374
N1%			
r	0.099	0.157	0.123
P value	0.214	0.048*	0.122
N2%			
r	0.280	0.278	0.020
P value	< 0.001*	< 0.001*	0.799
N3%			
r	-0.380	-0.484	-0.201
P value	< 0.001*	< 0.001*	0.011*
Obstructive apnea			
r	0.349	0.480	0.296
P value	< 0.001*	< 0.001*	< 0.001*
Hypopnea			
r	0.007	0.090	0.004
P value	0.933	0.259	0.960
AHI/Total			
r	0.455	0.509	0.322
P value	< 0.001*	< 0.001*	< 0.001*
AHI/NREM			
r	0.450	0.512	0.328
P value	< 0.001*	< 0.001*	< 0.001*
AHI/REM			
r	0.403	0.344	0.186
P value	< 0.001*	< 0.001*	0.019*
Average HR			
r	0.030	0.065	0.147
P value	0.714	0.424	0.069
Average O ₂			
r	-0.370	-0.264	-0.141
P value	< 0.001*	0.001*	0.075
Lowest O ₂			
r	-0.340	-0.304	-0.200
P value	< 0.001*	< 0.001*	0.011
Desaturation Index			
r	0.471	0.449	0.251
P value	< 0.001*	< 0.001*	0.002*
Arousal index			
r	0.235	0.364	0.233
P value	0.003*	< 0.001*	0.003*
Snoring index			
r	0.178	0.168	0.141
P value	0.035*	0.047*	0.096

r: correlation coefficient, AHI/Total: apnea hypopnea index/total sleep time, N1: sleep stage N1, N2: sleep stage N2, N3: sleep stage N3, NREM: nonrapid eye movement, REM: rapid eye movement, HR: heart rate. *P values less than 0.05 were considered statistically significant.

significant negative association ($P<0.05$) was noted between WHR with N3% and lowest O₂.

The receiver operating characteristic curve results of this work revealed that BMI, NC, and WHR were the most significant predictors of OSA ($P<0.001$); cut-off value of 34.35 kg/m² for BMI was a significant predictor for OSA with AUC 0.742 (95% CI : 0.675–0.808), 73.2% sensitivity and 69.4% specificity. Cut-off value of 42.5 cm for NC was a significant predictor for OSA with AUC 0.773 (95% CI : 0.712–0.835), 68.3% sensitivity, and 75.5% specificity. The cut-off value of 1.0259 for WHR was a significant predictor for OSA with AUC 0.663 (95% CI : 0.593–0.734), 59.9% sensitivity, and 65.3% specificity (Table 5, Fig. 4).

Discussion

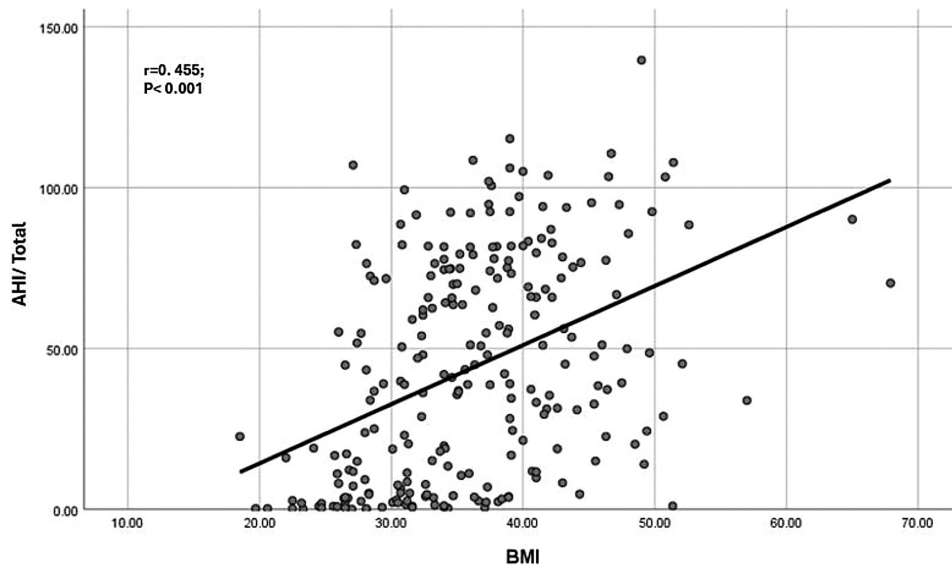
OSA is highly associated with obesity, and it is considered the most encountered sleep-related breathing disorder, particularly in male patients [17,18]. The current study aimed to determine the cut-off values of the BMI, WHR, and NC that can be used to evaluate and predict the severity of OSA in 241 Egyptian male patients who underwent polysomnography.

In the current work, patients with severe AHI were significantly older on the contrary to patients without OSA ($P<0.05$). In accordance with our results, Earl *et al.* [19] found that age greater than or equal to 50 years was independently predictive of moderate to severe OSA. Moreover, the results of a meta-analysis conducted by Heinzer and colleagues reported an association between older age and increased severity of OSA [20]. In addition, another study reported that age is associated with OSA severity only in men who were not obese [21].

Regarding sleep parameters, severe AHI was associated with significantly lower average O₂ saturation levels. Rezaie and colleagues results showed that there was a significant difference in mean oxygen saturation among those with severe and those with mild OSA, with the severe group having lower mean oxygen saturation values [17]. Additionally, patients with moderate and severe AHI had significantly higher snoring index when compared with the control group ($P<0.05$). In line with our study, an association between larger uvula size, increased snoring, and severe OSA was previously reported in the Chang *et al.* meta-analysis [22].

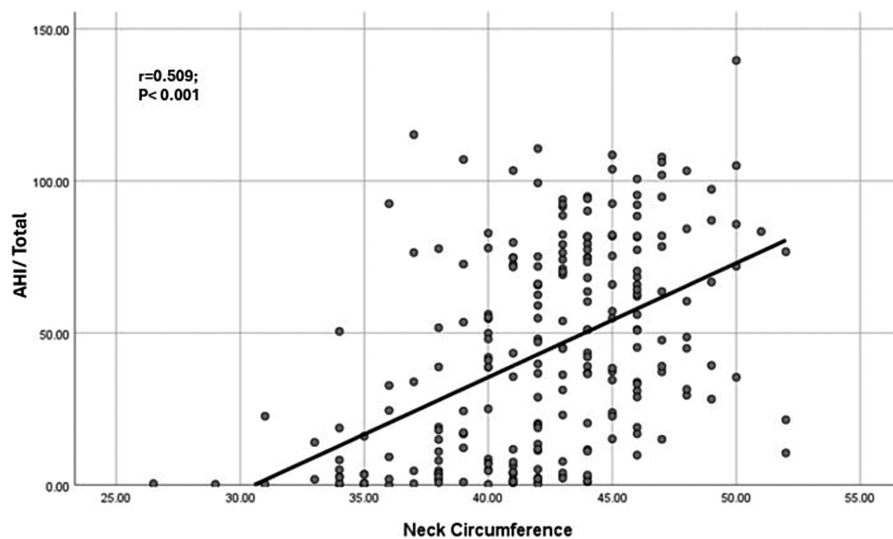
Of note, the severity of the sleep parameters, most importantly the AHI, has been recently associated with several complications and daytime sleepiness [23,24].

Figure 1



Spearman's correlation between body mass index with apnea hypopnea index/total.

Figure 2



Spearman's correlation between neck circumference with apnea hypopnea index/Total.

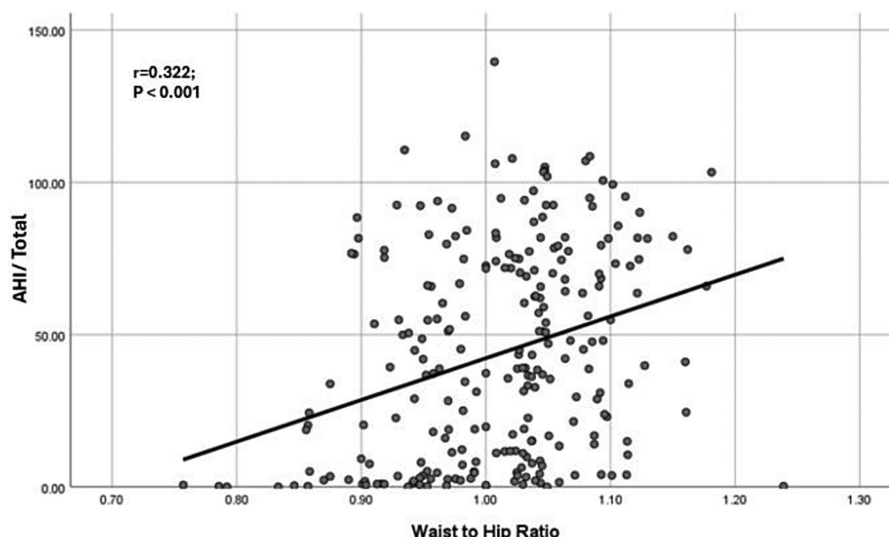
Furthermore, OSA has been coined with worsening respiratory, cardiovascular, and metabolic morbidity and increased risks of death [25–30]. Above all, evidence in western populations has demonstrated an exponential interaction between weight increase, as assessed by obesity indices (BMI, WHR, NC), and the occurrence of OSA [31–34] while data exploring this causal relationship in our population is limited with a small number of patients in rare publications [12,35].

Hence, an important finding in the present studied cohort, that those with severe OSA had significantly

higher BMI when compared with the control group and patients with mild OSA ($P<0.05$). In agreement with our findings, Rezaie *et al.* [17] reported that individuals with severe OSA had a higher BMI compared with those with mild to moderate OSA. Also, Earl *et al.* found that BMI greater than or equal to 38 kg/m^2 for males was an independent predictor of moderate to severe OSA [19].

Increased severity of AHI in the current study was as well associated with significantly higher NC and significantly higher WHR when compared with the group without OSA ($P<0.05$). Supporting our

Figure 3



Spearman's correlation between waist to hip ratio with apnea hypopnea index/total.

Table 5 Receiver operating characteristic curve for prediction of severe obstructive sleep apnea

	Area Under Curve	P value	95% Confidence Interval		Cut-off	Sensitivity %	Specificity %
			Lower Bound	Upper Bound			
Body Mass Index (kg/m ²)	0.742	< 0.001*	0.675	0.808	34.35	73.2	69.4
Neck circumference (cm)	0.773	< 0.001*	0.712	0.835	42.5	68.3	75.5
Waist to Hip Ratio	0.663	< 0.001*	0.593	0.734	1.0259	59.9	65.3

*P values less than 0.05 were considered statistically significant.

finding, Earl *et al.* reported that NC greater than or equal to 43.18 cm for males was independently predictive of moderate to severe OSA [19].

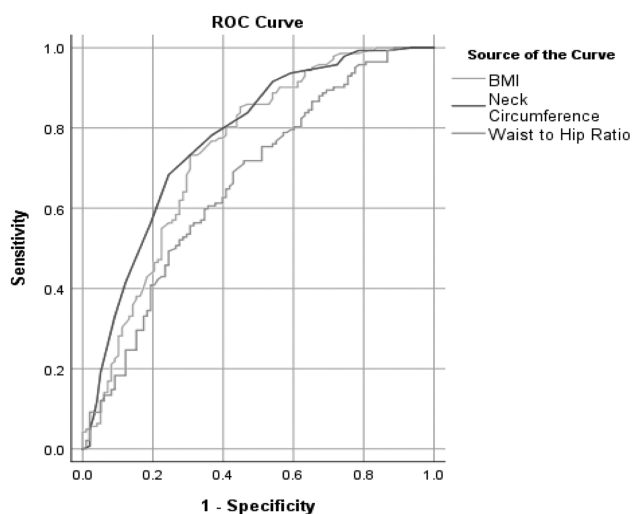
Fundamentally, the present study also revealed that cut-off measures for BMI (34.35 kg/m²), NC

(42.5 cm), and WHR (1.0259) were the most significant ($P < 0.001$ for all) predictors of severe OSA in our studied cohort of Egyptian male patients. Noteworthy, in a study of almost 150 patients, 0.92 was considered an optimum cut-off to predict OSA [11] whereas, Wang *et al.* [36] included around 240 patients with OSA and reported that WHR cut-off point of 0.873 yielded a sensitivity of 65% and specificity of 56% ($P < 0.05$) when used as a screening tool for moderate-to-severe OSA. The difference in the values observed in our results and other mentioned studies can be explained by the different ethnic backgrounds of the studied populations, particularly with data highlighting that Egyptians have raised levels of obesity [5].

Even though the severity of OSA was only associated with BMI and not NC in a study conducted on a small number of chronic obstructive pulmonary disease patients [37], our findings agree with previous studies [38,39] that showed that NC, waist circumference, hip circumference, and BMI grade were reliable and independent risk factors of OSA.

Despite the strength of our results, this study was limited by the fact that females were not included

Figure 4



Receiver operating characteristic curve for prediction of severe Obstructive Sleep Apnea.

since females probably explain their sleep disturbances to be due to insomnia and/or they are seldom referred for polysomnography due to cultural and traditional reasons. Nevertheless, various studies demonstrated that OSA is more frequently diagnosed in men due to the male sex's central fat distribution while it would be observed in females only after menopause possibly due to hormonal factors [40,41].

Conclusion

In conclusion, this study reported that increased BMI, NC and WHR were the most significant predictors of OSA and correlated with the severity of disease in male patients. In addition, the severity of the disease was associated with old age, increased indices of desaturation, snoring, and arousals, and the reduction in O₂ saturation during sleep. However, it is recommended that further multicentered studies should be done to be able to extrapolate these findings and these cut-off measures on the general Egyptian population.

Authors' contributions: A.G.: data acquisition, data analysis, literature search, manuscript preparation, manuscript editing, and review. M.S.E.: statistical analysis, manuscript editing and review. Y.H.E.-H.: manuscript review. G.H.: literature search, manuscript review.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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