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RESEARCH ARTICLE
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CLINICAL AND CARDIOMETABOLIC RISK FACTORS AND UPPER AIRWAY CHARACTERISTICS ASSOCIATED WITH HIGH RISK OF OBSTRUCTIVE SLEEP APNEA IN ADULTS

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Abstract

Obstructive sleep apnea (OSA) is linked with important clinical, cardiometabolic, anthropometric, and upper-airway abnormalities. Early identification of adults at high risk may support timely clinical evaluation and referral. This secondary observational analytical study included 343 adults classified as having high or low OSA risk. Demographic, clinical, behavioral, cardiometabolic, anthropometric, sleep-related, and upper-airway characteristics were evaluated. Continuous variables were analyzed with the independent-samples t-test, categorical associations were investigated using the chi-square test, and the relationships among continuous variables were assessed using Pearson correlation, and logistic regression was used to find factors linked to high OSA risk. 44.31% of subjects had a high OSA risk. High-risk individuals showed greater daytime sleepiness, body weight, BMI, neck circumference, and abdominal circumference. Snoring, sleepiness category, BMI category, hypertension, smoking, and marital status were significantly associated with OSA risk. Significant upper-airway associations were observed for palatopharyngeal insertion, Friedman tongue position, tongue abnormality, and palatopharyngeal gap. Strong positive correlations were found among obesity-related anthropometric measures. Logistic regression further identified snoring, obesity, high daytime sleepiness, hypertension, smoking, increased anthropometric measures, and selected upper-airway characteristics as significant individual factors related with high OSA risk. High OSA risk was closely related to symptomatic, cardiometabolic, anthropometric, and selected upper-airway characteristics.

Combining routine clinical assessment with anthropometric and upper-airway evaluation may improve early identification of adults requiring further diagnostic assessment.

Keywords: obstructive sleep apnea; cardiometabolic risk; obesity; upper airway; snoring

Introduction

One of the most prevalent respiratory problems related to sleep is obstructive sleep apnea (OSA), which results in intermittent hypoxia, sleep fragmentation, and frequent arousals due to a recurrent, partial, or total obstruction of the upper airway during sleep. Affected adults often go undiagnosed until symptoms or associated comorbidities come to light. Early detection of those with high risk is therefore important as untreated OSA is linked to difficulty concentrating, decreased quality of life, excessive daytime sleepiness, and increased cardiovascular/metabolic burden. Sleeping positions and lifestyle and behavioral factors may also play a role in a susceptibility to OSA. Smoking has been shown to serve as a risk factor for sleep-disordered breathing, and has been found to affect cardiometabolic risk in different ways for men and women (Ioannidou et al., 2021). Recurrent nocturnal hypoxia and sympathetic activation can also further lead to hypertension, metabolic dysfunction and cardiovascular complications (Hoyos et al., 2017). Assessment of clinical parameters like daytime somnolence, obesity, and co-existing medical conditions can be helpful to identify adults who are at higher risk for OSA (Ersoy & Mercan, 2021). The anthropometric measures are especially significant as they can influence the collapsibility of the upper airways and cardiometabolic outcomes related to excess body mass and central fat deposition. Thus, body mass index (BMI), neck circumference and abdominal circumference can be a good risk marker for OSA (Cemal, 2022). Large population-based studies also show that OSA risk is a combination of demographic, lifestyle and clinical factors and not just one of them alone (Thompson et al., 2022).

Cardiovascular risk is also associated with OSA, further underscoring the need for a thorough clinical assessment. Sleep-disordered breathing often co-occurs with hypertension and other abnormalities of the cardiovascular system, indicating that there is significant overlap between OSA and cardiovascular risk factors (Gać et al., 2022). This relationship can be partly attributed to the presence of endothelial dysfunction, which includes oxidative stress, inflammatory responses, and vascular dysfunction (Peracaula et al., 2022). Anthropometric measurements could also be used to identify cardiometabolic abnormalities in those with OSA (Balat et al., 2021); and diet and metabolic measurements suggest that the disease should be considered from a cardiometabolic perspective (Stelmach-Mardas et al., 2017). Apart from these systemic factors upper air-way anatomy may be a risk factor for OSA. The narrowing of the air passages during sleep can result from nasal obstruction, enlargement of the tonsils, configuration of the tongue, uvular and palatal shape, macroglossia, and palatopharyngeal configuration. Hence, clinical screening tests like the Berlin Questionnaire might be useful to detect adults who need further investigation prior to confirmatory sleep testing.

Although much research has been done for OSA, many studies have been carried out on the single component of risk factors and not clinical, cardiometabolic, anthropometric and upper-airway characteristics all together. There have been some links between abnormalities and cardiovascular risk in OSA and craniofacial and upper-airway morphology, making it important to evaluate the anatomy (Zhang et al., 2021). There are also strong associations between cardiometabolic diseases (such as

obesity, hypertension, and metabolic dysfunction) and OSA, as well as the risk of cardiovascular disease (Zhao et al., 2019). Though the cardiovascular impact of sleep apnea is clearly established, the relationship between sleep apnea and cardiovascular impacts is still complicated (Floras, 2018). In older patients, OSA has been shown to be associated with a number of cardiometabolic risk factors (Wu et al., 2018), and there is some population-based evidence that these relationships may differ by age, sex and race (Geovanini et al., 2018). Routine clinical characteristics, anthropometric and cardiometabolic measurements and detailed upper-airway characteristics have not been studied simultaneously in the same adult population, however.

A detailed evaluation of all of these areas could be beneficial in identifying high-risk adults with OSA. The clinical findings and traditional risk factors continue to be relevant in identifying which patients are in need of more sleep testing (Tawaranurak et al., 2019) and the severity of OSA has been linked to demographic, anthropometric and clinical features (Zhou et al., 2020). Cardiometabolic indices could also be used as a guide to the cardiovascular vulnerability of people with hypertension and OSA (Cai et al., 2022). Other important medical outcomes have also been associated with high-risk OSA status in adults with other medical conditions, highlighting the need for prompt identification of OSA risk (Peker et al., 2021). Thus, clinical, cardiometabolic, anthropometric and upper-airway factors combined could be a practical way to identify high risk individuals, especially when polysomnography is not readily available.

Research Objectives

1. To determine the clinical, behavioral, anthropometric, and cardiometabolic characteristics of adults according to their risk of OSA.
2. To assess the relationship between increased risk of OSA in adults and upper-airway anatomical features.
3. To identify the clinical, cardiometabolic, anthropometric, and upper-airway factors linked to high risk of OSA.

2. Methodology

2.1 Study Design

This research was designed as an analytical observational study using existing records of adult participants to investigate clinical, cardiometabolic, anthropometric, and upper-airway characteristics associated with high risk for OSA. Comparisons between adults with high- and low-risk OSA, and factors associated with high-risk adults were the focus of the analysis.

2.2 Study Population and Sample Size

The study involved 343 adults in total. 152 participants were categorized as having a high risk of OSA and 191 as having a low risk using the Berlin Questionnaire. Every participant record that was accessible was examined.

2.3 Data Source

The data were obtained from the publicly available Mendeley Data repository, High Risk of Obstructive Sleep Apnea Hospital (Version 1), deposited by Alcas (2018). The available records included demographic, clinical, behavioral, anthropometric, cardiometabolic, sleep-related, and upper-airway examination variables relevant to OSA risk assessment.

2.4 Assessment of Obstructive Sleep Apnea Risk

A Berlin Questionnaire was used to assess the risk of OSA, with groups being categorized as high-risk and low-risk. This classification did not necessarily indicate a diagnosis of OSA, but rather the risk for OSA based on screening results.

2.5 Demographic and Clinical Variables

Clinical and demographic variables were age, marital status, age group, sex, alcohol consumption, educational level, smoking status, depression or anxiety status, snoring status, Epworth Sleepiness Scale score, and sleepiness category. These variables were examined to determine if they are associated with high OSA risk.

2.6 Cardiometabolic and Anthropometric Variables

Cardiometabolic and anthropometric measurements included hypertension, diabetes mellitus, body weight, height, body mass index (BMI), BMI category, neck circumference and abdominal circumference. These measures were analysed to determine their association with high OSA risk.

2.7 Upper-Airway Assessment

The upper-airway characteristics were those of the nasal septal deviation, inferior turbinate size, tonsil size, tonsil group, Friedman tongue position, Friedman tongue position group, uvular characteristics, bony palate, soft palate, tongue enlargement or macroglossia, palatopharyngeal gap, palatopharyngeal insertion, palatopharyngeal muscle morphology, Angle classification, and Angle group. These anatomical features were examined to determine their association with OSA risk.

2.8 Outcome Variable

High risk of OSA by the Berlin questionnaire was the primary outcome variable. Patients who were deemed high risk were the primary outcome group, and patients who were deemed low risk were the comparison group.

2.9 Statistical Analysis

Data were reported as frequencies and percentages for categorical variables and as mean ± SD for continuous variables. The chi-square test was utilized to ascertain correlations between categorical factors and OSA risk, while independent-samples t-tests were employed to examine continuous variables between the high- and minimal-risk OSA groups. To analyse correlations between relevant continuous variables, both clinical, anthropometric and sleep-related ones, Pearson correlation analysis was performed. Logistic regression analysis was done to assess the individual association of selected clinical, cardiometabolic, anthropometric, and upper-airway parameters to high OSA risk. Statistical significance was set at a p-value of <0.05.

3. Results

3.1 Distribution of Obstructive Sleep Apnea Risk

A total of 191 adults (55.69%) were classified as low risk for OSA and 152 adults (44.31%) were categorized as high risk for OSA. The high-risk group accounted for a significant percentage of the sample population (Figure 1) despite being slightly smaller in number.

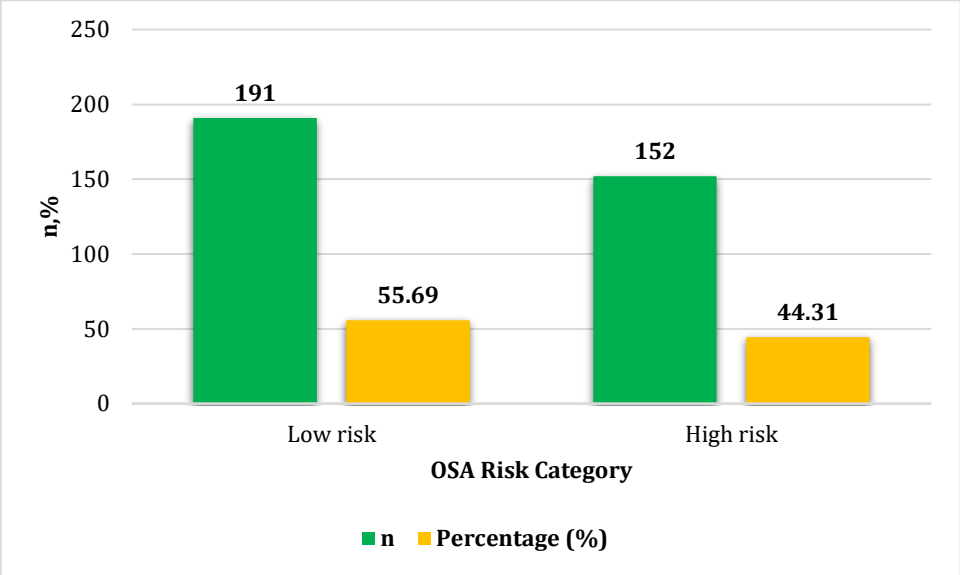

Figure 1. Distribution of participants according to obstructive sleep apnea risk

The figure demonstrates that a substantial proportion of participants belonged to the high-risk category, although the low-risk group remained slightly larger. This distribution allowed for a clinically appropriate further comparison of clinical, cardiometabolic, anthropometric, and upper-airway characteristics between the two groups.

3.2 Demographic and General Clinical Profile of Participants

The demographic profile indicated that most of the participants were middle-aged and older people, with a higher number of females as compared to males. The majority of participants were married, and the most common level of education was university. An overall distribution of the demographics is included in Table 1.

Table 1. Demographic Features

Characteristic	Category	n	Percentage (%)
Age (years)	Mean ± SD	58.68 ± 16.33	-
Sex	Female	190	55.39
	Male	153	44.61
Marital status	Single	111	32.36
	Cohabiting	23	6.71
	Widowed	31	9.04
	Married	178	51.90
Education	Incomplete secondary	51	14.87
	Completed secondary	86	25.07
	Technical higher education	70	20.41
	University higher education	136	39.65

The clinical/behavioural profile indicated that high frequency of smoking and alcohol consumption were rare. Hypertension was more common than diabetes mellitus and depression/anxiety, and snoring

was one of the most common clinical characteristics. Additionally, a clinically relevant number of participants had high daytime sleepiness, showing the presence of several clinical features related to OSA within the study population (Figure 2).

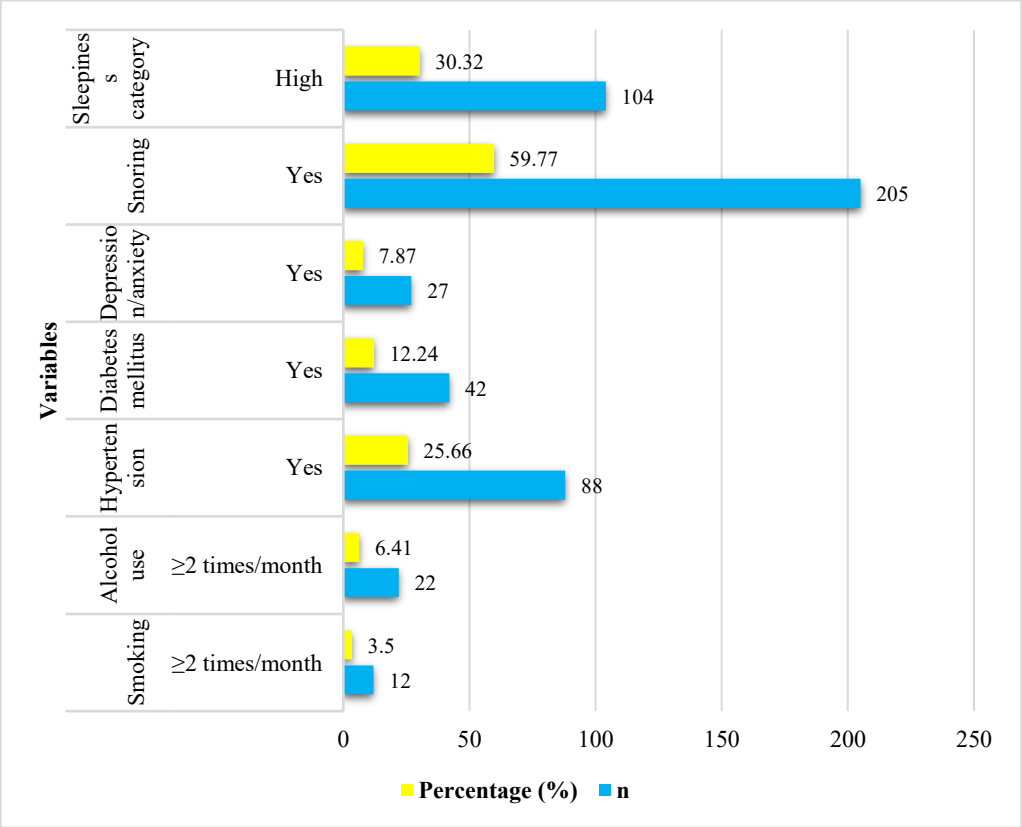

Figure 2. Clinical and Behavioral Characteristics of Participants

The figure also shows that snoring was the most prevalent clinical feature among all of the features presented, followed by high daytime sleepiness and hypertension. In comparison, diabetes mellitus, depression/anxiety, frequent alcohol use, and frequent smoking were less common.

3.3 Clinical and Cardiometabolic Factors Associated with OSA Risk

Several clinical and cardiometabolic variables were significantly connected with the OSA-risk classification, using the chi-square analysis. Snoring, sleepiness category, BMI category and hypertension were the ones that showed the most definite relationships, and smoking and marital status were found to be significantly related to the risk status. Sex, educational level, alcohol use, diabetes, age group, and depression/anxiety were not statistically significant. These results indicate that the relationships of some symptomatic sleep-related variables and obesity-related cardiometabolic variables with the high OSA risk were stronger than most of the other demographic variables (Table 2).

Table 2. Clinical and cardiometabolic factors associated with OSA risk

Variable	Chi-square	df	p-value
Snoring	126.069	1	<0.001
Sleepiness category	51.722	1	<0.001
BMI category	47.744	3	<0.001
Hypertension	37.189	1	<0.001
Smoking	6.121	1	0.013
Marital status	8.697	3	0.034
Depression/anxiety	3.350	1	0.067
Age group	6.738	3	0.081
Diabetes mellitus	2.627	1	0.105
Alcohol use	1.489	1	0.222
Education	0.169	3	0.982
Sex	0.000	1	1.000

3.4 Clinical and Anthropometric Characteristics According to OSA Risk

The clinical and anthropometric profile of the high-risk OSA group was worse than the low-risk group. All of the differences were statistically significant, with high-risk participants showing higher levels of daytime sleepiness, body weight, BMI, neck circumference and abdominal circumference. By contrast, age and height were similar between the two groups, suggesting that obesity-related and sleepiness-related characteristics showed clearer associations with OSA-risk status than age or height (Table 3).

Table 3. Comparison of continuous clinical and anthropometric characteristics according to OSA risk

Variable	Low risk, Mean ± SD	High risk, Mean ± SD	t statistic	p-value
Age (years)	57.25 ± 16.76	60.47 ± 15.65	1.821	0.069
Epworth score	5.56 ± 3.60	9.90 ± 4.58	9.840	<0.001
Weight	64.29 ± 11.77	70.97 ± 13.23	4.940	<0.001
Height	1.608 ± 0.087	1.600 ± 0.087	−0.849	0.397
BMI	24.80 ± 3.51	27.68 ± 4.41	6.729	<0.001
Neck circumference	36.40 ± 3.90	38.13 ± 4.09	4.004	<0.001
Abdominal circumference	88.46 ± 10.54	97.33 ± 11.15	7.543	<0.001

Mean clinical and anthropometric measurements of the two OSA-risk groups are graphically compared in Figure 3.

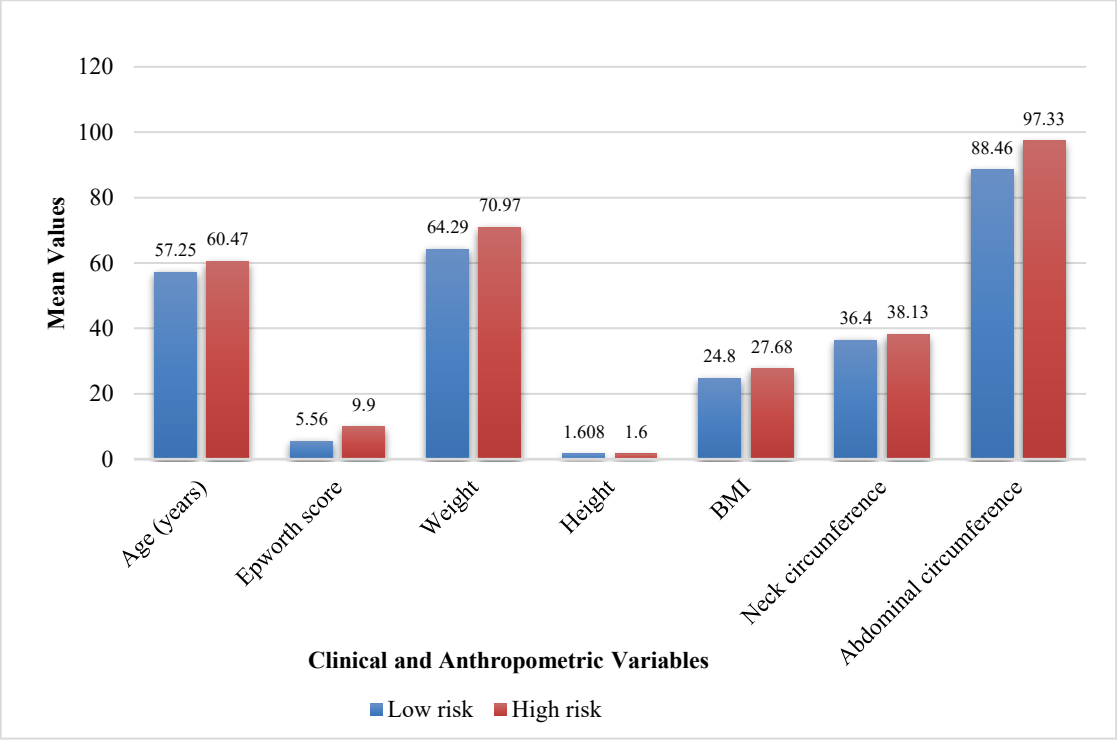

Figure 3. Mean Clinical and Anthropometric Measures by OSA Risk

The graphical pattern illustrates the differences between the low- and high-risk OSA groups for the clinical and anthropometric parameters tested. Some measures recorded virtually no visual differences between the groups, but others recorded more obvious differences, especially those pertaining to daytime sleepiness and body composition. Overall, the figure provides a clear visual comparison of the measured characteristics according to OSA-risk status.

3.5 Upper-Airway Characteristics Associated with OSA Risk

There were significant associations with OSA-risk status for several upper-airway parameters. Palatopharyngeal insertion, Friedman tongue position, grouped Friedman tongue position, tongue abnormality, and palatopharyngeal gap were shown to be significantly associated with high OSA risk. However, nasal septal deviation, inferior turbinate size, tonsillar characteristics, uvular morphology, bony and soft palate findings, palatopharyngeal muscle morphology and Angle classification were not significantly related to OSA risk. These findings suggest that selected oropharyngeal and tongue-related anatomical characteristics showed clearer associations with OSA-risk classification than the other upper-airway characteristics assessed (Table 4).

Table 4. Association of upper-airway characteristics with OSA risk

Upper-airway characteristic	Chi-square	df	p-value
Palatopharyngeal insertion	10.990	3	0.012
FTP group	9.725	3	0.021
Tongue	4.530	1	0.033
Palatopharyngeal gap	4.499	1	0.034
Friedman tongue position	9.746	4	0.045
Tonsil group	3.216	2	0.200
Palatopharyngeal muscle	2.946	2	0.229
Angle classification	2.889	2	0.236
Tonsil size	4.045	3	0.257
Soft palate	0.528	1	0.467
Nasal septum	0.478	1	0.489
Uvula	0.428	1	0.513
Angle group	0.149	1	0.700
Inferior turbinates	0.064	1	0.801
Bony palate	0.001	1	0.974

3.6 Correlations Among Clinical and Anthropometric Measures

The Pearson correlation analysis revealed significant associations between the clinical and anthropometric parameters. The highest positive correlations were found for obesity parameters like body weight, body mass index, neck circumference, and abdominal circumference. Some moderate correlations were noted between certain body size parameters, whereas Epworth sleepiness scale was found to have relatively weak positive associations with the adiposity parameters. Only weak associations were noted between the age and the anthropometric parameters (Figure 4).

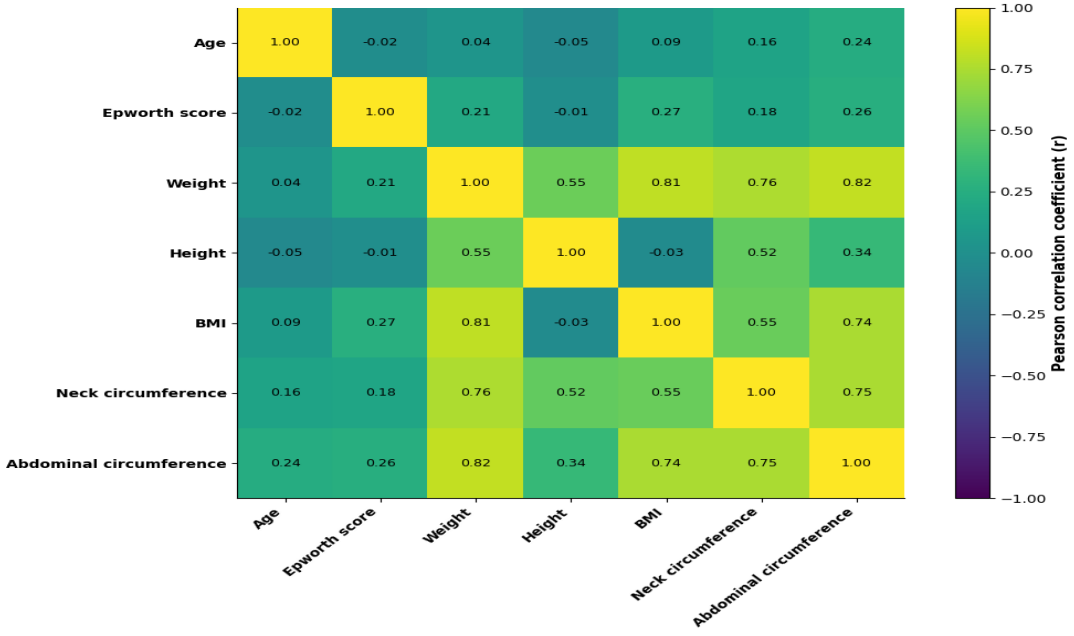

Figure 4. Heat map of Pearson correlations among clinical and anthropometric measures

The heatmap effectively shows the grouping of positive correlation among the anthropometric measurements in the obesity study while those of age and Epworth sleepiness score were less significant.

3.7 Logistic regression analysis of Factors Associated with High OSA Risk

Logistic regression showed several clinical, cardiometabolic, anthropometric, and upper-airway variables, each related with high risk of OSA. Among the factors, snoring and obesity category showed especially strong associations, and high daytime sleepiness and hypertension were among the risk-related factors. As the Epworth score, body weight, BMI, neck circumference and abdominal circumference increased, there was a corresponding rise in the odds of high OSA risk. Smoking, older age category, selected categories of marital status, palatopharyngeal gap, tongue abnormality, and depression/anxiety were also found to be individually significantly associated. These results show individual relationships between the symptomatic, cardiometabolic, anthropometric and selected upper-airway characteristics and the classification of high OSA risk (Table 5).

Table 5. Significant logistic regression findings for high OSA risk

Predictor	Odds ratio	95% CI	p-value
Epworth score	1.294	1.213–1.381	<0.001
Weight	1.044	1.025–1.063	<0.001
BMI	1.208	1.135–1.286	<0.001
Neck circumference	1.115	1.055–1.178	<0.001
Abdominal circumference	1.080	1.055–1.105	<0.001
High sleepiness category	6.236	3.720–10.453	<0.001
Snoring	28.851	14.203–58.603	<0.001
Hypertension	5.061	2.962–8.645	<0.001
Obesity category	36.800	4.125–328.290	0.001
Age group >80 years	3.667	1.290–10.426	0.015
Married status	1.837	1.125–2.998	0.015
Smoking	6.655	1.436–30.848	0.015
Widowed status	2.660	1.179–6.003	0.018
Palatopharyngeal gap	2.153	1.104–4.198	0.024
Macroglossia/tongue abnormality	4.413	1.193–16.331	0.026
Depression/anxiety	2.279	1.012–5.135	0.047

4. Discussion

The current study shows that a significant percentage of individuals were identified as having an elevated risk of OSA, and that the clinical and anthropometric characteristics of the high-risk group varied considerably. Increased daytime sleepiness, body weight, BMI, neck circumference, and abdominal circumference were all consistently found to be connected with high risk of OSA in the

investigations at hand, whereas age and height were associated with lesser or non-significant differences. The results suggest that factors measuring adiposity and upper-body fat distribution are more useful in the classification of OSA risk than are basic demographic factors alone. The observed strong association with snoring further confirms the usefulness of this easily recognisable clinical parameter, and high sleepiness and hypertension also came up as prominent risk-related factors. The overall results indicated that it was not a simple isolated sleep, obesity or cardiometabolic characteristic that identified high OSA risk, but rather a combination of sleep, obesity and cardiometabolic characteristics.

The upper-airway findings also provided important anatomical context. There were significant associations found for palatopharyngeal insertion, Friedman tongue position, grouped Friedman tongue position, tongue abnormality and palatopharyngeal gap. The results indicate that the structural characteristics impacting the oropharyngeal space and tongue position can collectively play a significant role in OSA-risk classification. Several other anatomical parameters such as tonsillar size, morphology of the nasal septum, size of inferior turbinates, uvular morphology, bony palate, soft palate and Angle classification did not show any significant differences between risk and non-risk groups. The correlation analysis also revealed that body weight, BMI, neck circumference and abdominal circumference were highly correlated, suggesting that they measure similar aspects of fatness. Because they are both associated with high OSA risk, central and cervical fat distribution argue for its importance when clinically evaluating adults at risk for sleep-disordered breathing.

The present results suggest that OSA is connected with cardiovascular and metabolic risk, which is in line with earlier evidence. Tietjens et al (2019) pointed out how intimately linked OSA and cardiovascular disease are and the need to consider OSA in the cardiovascular risk profile. In a similar manner, the scientific statement from Yeghiazarians et al. (2021) from the American Heart Association states that OSA is recognized as an important condition that may contribute to hypertension and cardiovascular morbidity and cardiometabolic impacts. The high association noted in the present investigation with hypertension, obesity measures, and sleepiness are thus in accord with this well-known clinical framework. The results are also consistent with the work of Gaines et al (2018), which discussed the correlation of OSA and metabolic syndrome, and further highlighted that there is no single clinical representation of OSA. Also, BMI, abdominal circumference, and neck circumference were prominent in the results of this study, which also agrees with previous findings that obesity is a significant adaptable risk factor for OSA. Hamilton and Joosten (2017) reported that obesity is one of the most significant modifiable risk factors for OSA, since obesity can lead to upper airway narrowing and decreased respiratory mechanics. Furthermore, the diabetes related cardiometabolic burden presented with OSA by Su et al. (2021) strengthens the association between sleep-disordered breathing and metabolic disease in general, despite the lack of a significant association between diabetes and OSA-risk classification in the current analysis.

Clinical screening is affected by these findings. Individuals who are more inclined to be in a high-risk group for OSA can be identified by a straightforward assessment of snoring, daytime drowsiness, hypertension, BMI, neck circumference, stomach circumference, and some upper-airway characteristics. This method could be especially helpful at facilities where polysomnography resources are scarce or cannot be obtained in a timely fashion. The findings also support a multifaceted clinical

approach in which cardiometabolic assessment and focused upper-airway examination complement symptom-based screening for OSA risk.

This study has a number of limitations. This was an observational study, and no causal conclusions can be drawn. The OSA status was determined by risk classification and not by polysomnography diagnosis, and the apnea-hypopnea index value was not available. The number of subjects in some of the categorical variables was rather small, which may explain the broadness of the confidence intervals in the regression analysis. Moreover, the regression models tested each predictor separately and did not consider the effect of more than one predictor.

These results should be validated in future studies involving larger and more diverse populations with polysomnography-confirmed OSA. Multivariable models should also be created to identify which clinical, cardiometabolic, anthropometric and upper-airway characteristics continue to be important when considered in combination. Future research could also evaluate the utility of using a combination of anthropometric parameters, symptom profile, and upper airway examination for the early detection of OSA and accuracy of referral.

5. Conclusion

The current investigation revealed that a substantial proportion of adults were at high risk of OSA, and showed that the risk for OSA was tightly linked to a cluster of clinical, cardiometabolic, anthropometric and upper airway factors. Groups at high OSA risk exhibited higher daytime sleepiness, body weight, BMI, neck circumference and abdominal circumference, with no significant difference in risk with regard to age and height. Both symptomatic and cardiometabolic factors were significantly associated with OSA-risk classification: snoring, high sleepiness, obesity category, hypertension, smoking and marital status. Several upper-airway characteristics were found to be significantly associated with high OSA risk, while others, including several nasal, tonsillar, palatal and dental characteristics, were not found to be significantly related to a high-risk status. The weight, BMI, neck circumference, and abdominal circumference were also well correlated with each other, which further highlighted the interdependency of obesity anthropometric measurements. Logistic regression also demonstrated that snoring, obesity, high daytime sleepiness, hypertension, smoking, tongue abnormality, and anthropometric measurements were significant individual factors associated with high OSA risk. In sum, these results can help to facilitate the use of a comprehensive clinical strategy for identifying adults at high risk of OSA and prompt timely referral for additional evaluation.

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