RESEARCH ARTICLE

The Association of Polysomnographic Variables with BMI, Gender, and Age in Sudanese Adults with Obstructive Sleep Apnea

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Abstract

Background: Obstructive sleep apnea (OSA) is a common sleep-related breathing disorder characterized by repeated upper airway collapse during sleep. Despite its global prevalence, data on OSA in Sudanese populations remain limited. This study aimed to explore the relationship between polysomnographic variables and body mass index (BMI), gender, and age in Sudanese adults with OSA.

Methods: This retrospective study analyzed polysomnography data from 251 Sudanese adults. Given the non-normal distribution of sleep data, non-parametric tests were used. OSA severity was classified using the apnea-hypopnea index (AHI). Key parameters—AHI, arousal index, desaturation index, sleep efficiency, and snoring—were analyzed against BMI, age, and gender using Mann-Whitney U tests, Kruskal-Wallis tests, and Spearman's rank correlation. A negative binomial generalized linear model (GLM) was used to assess predictors of AHI.

Results: BMI showed a moderate positive correlation with AHI (Spearman's rho = 0.307, p < 0.001) and desaturation index (rho = 0.342, p < 0.001). AHI increased significantly across BMI categories (p < 0.001), with obese class III patients showing the highest median AHI. Age was negatively correlated with sleep efficiency (rho = -0.230, p < 0.001). Males had significantly higher arousal index (p < 0.001) and snoring (p = 0.016) than females, but AHI did not differ significantly between genders. The GLM regression confirmed BMI as a significant independent predictor of higher AHI (Incidence Rate Ratio = 1.024, p = 0.002).

Conclusion: In this Sudanese cohort, BMI was the most significant factor associated with OSA severity. Increasing age was linked to poorer sleep efficiency. While males exhibited more sleep disruption, OSA severity (AHI) was comparable between genders, highlighting the importance of considering OSA in females. These findings underscore the need for weight management strategies in managing OSA in this population.

Keywords: Obstructive Sleep Apnea, Polysomnography, Body Mass Index, Apnea-Hypopnea Index, Sudanese Population.

Introduction

Recurrent episodes of upper airway narrowing or obstruction during sleep, which result in a significant decrease or halt of airflow, oxygen desaturation, and frequent arousals, are the hallmarks of obstructive sleep apnea (OSA) [1,2]. In the United States, it is a prevalent illness that is more common in men and becomes more prevalent as people age, with an estimated 26% prevalence among patients between the ages of 30 and 70.[3] The apnea-hypopnea index (AHI), or the average number of apneas and hypopneas per hour of sleep, is used to gauge the

severity of the disorder. When an AHI of ≥5 is combined with daytime sleepiness, it is referred to be OSA, and when it is ≥5, it is called OSA syndrome. Daytime sleepiness was classified as mild, moderate, or severe by the American Association of Sleep Medicine based on how it affected social interactions during the day [3]. Patients with obstructive sleep apnea are being treated differently in each nation based on their individual symptoms. Although significant efforts are being made in settings with adequate resources to detect and treat obstructive sleep apnea, research indicates that even in industrialized nations, the majority of instances of obstructive sleep apnea go misdiagnosed and untreated. Obstructive sleep apnea is often not well known in underdeveloped nations, and available diagnostic and treatment solutions are frequently unavailable or have not been modified for environments with limited resources [4]. Obstructive sleep apnea is linked to a significant economic and societal burden because to its complex and social effects. The estimated cost of diagnosing and treating obstructive sleep apnea in the United States was $12.4 billion in 2015 [4]. Research indicates that obstructive sleep apnea plays a significant role in adverse health outcomes and that in general, treating this illness helps to improve sleep-related quality of life and reduce related negative clinical consequences [5]. A group of cardiovascular risk factors known as metabolic syndrome (MS) include high blood pressure, overweight or obesity, hypertriglyceridemia, low HDL-C (high-density lipoprotein cholesterol), and glucose intolerance. When three or more of the five distinct components are present in the same person, MS is diagnosed in adults and, more recently, in children and adolescents. MS is a significant risk factor for chronic illnesses and is becoming more common due to a sedentary lifestyle and increased childhood obesity [6]. When there is no other neuromuscular, mechanical, or metabolic explanation for hypoventilation, obesity (body mass index (BMI) ≤30 kg·m^{-2}), sleep disturbance, and daytime hypercapnia (arterial carbon dioxide tension ($PaCO_2$) ≥45 mmHg at sea level) during wakefulness are combined to form obesity hypoventilation syndrome (OHS). An apnea/hypopnea index (AHI) of ≤5 occurrences h^{-1} indicates obstructive sleep apnea (OSA), which affects about 90% of individuals with OHS. Concomitant severe OSA is seen in about 70% of patients (AHI ≤30 events·h^{-1}) [7]. The prevalence of OSA has not been directly examined between racial groups in many research. Furthermore, comparisons of OSA prevalence among research are limited by the absence of uniform criteria for defining OSA. However, the data that is currently available shows that the prevalence of OSA is higher among African Americans, Hispanics, and Native Americans than among US whites, whereas the prevalence among Asians seems to be on level with whites [8]. Sudanese adults represent a distinct population for OSA research due to their unique genetic predispositions, environmental exposures, and cultural practices, which may influence the condition's prevalence, severity, and clinical presentation [9]. Variations in dietary habits, body composition, and access to healthcare may further modulate the relationship between key risk factors, such as BMI, and OSA severity [10]. While obesity is a recognized major risk factor for OSA, non-obese individuals may also develop OSA due to structural abnormalities of the upper airway, underscoring the complexity of the condition. Despite the growing prevalence of obesity in Sudan and its known association with OSA, limited studies have investigated these associations in Sudanese adults, highlighting the need for focused research in this population [11,12]. Existing evidence suggests that OSA is more prevalent in males and increases with age, with obesity playing a significant role in its development and progression [13,14]. However, gender and age differences in OSA severity and clinical manifestations remain poorly understood, particularly in African populations. For instance, females with OSA often report symptoms such as fatigue, insomnia, and mood disturbances, while males more commonly present with snoring and observed apneas. Hormonal fluctuations, particularly in women, add another layer of complexity to understanding how gender impacts OSA severity [15]. Additionally, older adults often experience reduced sleep efficiency and worsening OSA severity due to age-related changes in upper airway anatomy and neuromuscular control. This study aims to investigate the association of polysomnographic variables with BMI, age, and gender in Sudanese adults diagnosed with OSA. This research meets the need for region-specific data by focusing on an understudied population. The findings are expected to provide valuable insights into the multifactorial nature of OSA and inform tailored management strategies for a diverse population.

This study hypothesizes that in Sudanese adults with OSA, higher BMI and male gender will be associated with greater OSA severity, as indicated by a higher AHI, while increasing age will be associated with reduced sleep efficiency.

Methods

This study retrospectively analyzed 251 adult patients diagnosed with obstructive sleep apnea (OSA) through polysomnography (PSG) conducted between January 2020 and January 2021. Participants were recruited from the Sleep Study Center at the Military Hospital in Khartoum, Sudan. Patients were identified based on clinical indications for OSA, including symptoms like excessive daytime sleepiness, loud snoring, witnessed apneas, and unrefreshing sleep. Recruitment was conducted through referrals from primary care physicians and specialists and direct consultations at the sleep center. Ethical approval for the study was obtained from the Faculty of Medicine's ethics committee at the International Africa University (IRB Approval Number: IAU-EC-2020-015).

Inclusion and Exclusion Criteria

Inclusion criteria required participants to be adults aged 18 years or older with a confirmed diagnosis of OSA based on PSG results. Exclusion criteria included the presence of other sleep disorders (e.g., central sleep apnea, restless leg syndrome), significant comorbidities that could influence sleep parameters (e.g., advanced heart failure, chronic obstructive pulmonary disease), or prior treatment for

OSA (e.g., continuous positive airway pressure therapy). Patients with incomplete or poor-quality PSG data were also excluded from the analysis. The sample size was determined by the number of eligible patients who underwent PSG at the center during the study period.

Polysomnography and Classification

Each participant underwent a single night of laboratory-based PSG using the Grass-Comet Plus system. The apnea-hypopnea index (AHI) was calculated to classify OSA severity according to the World Health Organization's criteria: no/minimal OSA (AHI < 5), mild OSA (AHI = 5–15), moderate OSA (AHI = 16–30), and severe OSA (AHI > 30). Body mass index (BMI) was calculated as weight divided by the square of height (kg/m²). Participants were categorized into four age groups: 18–30, 31–49, 50–64, and 65 years and above.

Statistical Analysis

Data analysis was performed using Python (version 3.11) with the scipy, statsmodels, and pyreadstat libraries. The normality of continuous variables was assessed using the Shapiro-Wilk test. All key sleep parameters (sleep efficiency, arousal index, AHI, desaturation index, snoring) demonstrated significant deviation from a normal distribution (all $p < 0.001$), confirming the appropriateness of non-parametric methods.

Descriptive statistics are presented as median and interquartile range (IQR). The Mann-Whitney U test (an equivalent of the independent samples t-test) was used to compare medians between two independent groups (gender). The Kruskal-Wallis test was employed to analyze differences across more than two groups (BMI and age categories), as it is robust to unequal group sizes and non-normal distributions. Spearman's rank correlation coefficients were calculated to evaluate the monotonic relationship between continuous variables (BMI, age) and sleep parameters.

To control for the increased risk of Type I errors from multiple comparisons, a Bonferroni correction was applied to the significance level ($\alpha = 0.05$), resulting in a corrected threshold of $p < 0.002$ for the 25 primary tests conducted.

Given the skewed, overdispersed count nature of the AHI, a negative binomial generalized linear model (GLM) was employed to assess the independent effects of BMI, age, and gender on AHI. This approach does not assume normality of the outcome variable and is more appropriate than standard linear regression. Results from the GLM are reported as Incidence Rate Ratios (IRR) with 95% confidence intervals (CI). For all tests, a p-value ≤ 0.05 was considered statistically significant, with the Bonferroni-corrected threshold applied for multiple comparisons.

Results

A total of 251 patients were diagnosed with obstructive sleep apnea (OSA), comprising 134 males (53%) and 117 females (47%). The demographic characteristics of the study participants, including age, gender, and body mass index (BMI) categories, are summarized in Table 1. The majority of participants were aged 50–64 years (42.6%), followed by those aged 65 years and above (29.5%). Regarding BMI, 34.3% of participants were classified as having obesity class III (BMI ≥ 40 kg/m²), highlighting the strong association between obesity and OSA in this cohort. Only 2.4% of participants had a normal BMI, while the majority fell into overweight or obese categories. This distribution underscores the importance of BMI as a key factor in the prevalence and severity of OSA.

Table 1: Demographic Distribution of Patients (N=251)

Characteristic	Category	N (%)	Min-Max
Age			19-90
	18-30	11 (4.4%)	
	31-49	59 (23.5%)	
	50-64	107 (42.6%)	
	Over 65	74 (29.5%)	
Gender			
	Males	134 (53.4%)	
	Females	117 (46.6%)	
BMI			18.9-84.3
	Normal (18.5-24.9)	6 (2.4%)	
	Overweight (25-29.9)	30 (12.0%)	
	Obesity Class I (30-34.9)	73 (29.1%)	
	Obesity Class II (35-39.9)	56 (22.3%)	
	Obesity Class III (≥40)	86 (34.3%)	

Polysomnographic parameters across BMI categories are presented in Table 2. While sleep efficiency did not differ significantly across BMI groups, the apnea-hypopnea index (AHI), desaturation index, and snoring all increased significantly with higher BMI categories (all $p < 0.05$). A clear dose-response relationship was observed, with participants in the obesity class III group exhibiting the highest median AHI of 51.0 (IQR: 20.9–77.5), compared to a median of 4.3 (IQR: 2.7–7.5) in the normal weight group.

The correlation between continuous BMI, age, and sleep study parameters is shown in Table 3. BMI was moderately and positively correlated with AHI (rho = 0.307, $p < 0.001$) and desaturation index (rho = 0.342, $p < 0.001$). Age was weakly but significantly negatively correlated with sleep efficiency (rho = -0.230, $p < 0.001$), indicating that older individuals tend to have reduced sleep efficiency.

Age-related differences in sleep study parameters are summarized in Table 4. Sleep efficiency showed a significant decline with increasing age ($p = 0.005$), with the oldest group (≥65 years) exhibiting the lowest median sleep efficiency. AHI values also varied significantly across age groups ($p = 0.027$), with the highest values observed in the 31–49 age group.

Gender differences in sleep study parameters are presented in Table 5. Males had significantly higher arousal index and snoring intensity compared to females. However, AHI and desaturation index values did not differ significantly between genders.

Table 2: Sleep Study Parameters by Body Mass Index Groups (Median (IQR))

Parameter	Normal (n=6)	Overweight (n=30)	Obesity I (n=73)	Obesity II (n=56)	Obesity III (n=86)	p-value
Sleep Efficiency	88.7 (85.5-92.0)	85.9 (75.1-91.3)	84.6 (77.0-92.0)	79.0 (67.0-90.3)	79.6 (67.7-92.0)	0.218
Arousal Index	10.7 (9.2-15.6)	11.7 (6.5-15.9)	17.0 (7.9-27.4)	17.3 (7.2-33.0)	17.3 (10.5-30.3)	0.128
AHI	4.3 (2.7-7.5)	10.4 (5.1-43.2)	35.0 (13.5-57.3)	45.5 (26.5-69.6)	51.0 (20.9-77.5)	<0.001*
Desaturation Index	2.7 (2.0-5.4)	18.0 (8.5-56.6)	40.0 (17.4-69.3)	64.9 (31.8-81.8)	63.0 (26.1-84.0)	<0.001*
Snoring	23.1 (5.7-30.4)	12.6 (7.6-29.2)	23.0 (14.0-34.6)	28.3 (15.3-36.2)	28.5 (20.5-40.6)	0.024*
*Significant at p < 0.05. Results for AHI and Desaturation Index also survive Bonferroni correction (p < 0.002).						

Table 3: Spearman Correlation of BMI and Age with Sleep Study Parameters

Parameter	vs. BMI (rho)	p-value	vs. Age (rho)	p-value
Sleep Efficiency	-0.156	0.014*	-0.230	<0.001*
Arousal Index	0.181	0.005*	-0.025	0.703
AHI	0.307	<0.001*	0.038	0.545
Desaturation Index	0.342	<0.001*	0.101	0.114
Snoring	0.191	0.002*	0.058	0.360
*Significant at p < 0.05. Results for AHI and Desaturation Index also survive Bonferroni correction (p < 0.002).				

Table 4: Sleep Study Parameters by Age Groups (Median (IQR))

Parameter	18-30 (n=11)	31-49 (n=59)	50-64 (n=107)	≥65 (n=74)	p-value
Sleep Efficiency	85.0 (81.0-89.5)	88.6 (79.1-94.0)	81.4 (68.6-91.5)	78.9 (66.0-89.0)	0.005*
Arousal Index	16.9 (9.7-19.8)	22.0 (10.5-31.2)	15.0 (6.9-26.1)	15.2 (7.4-24.4)	0.374
AHI	4.0 (2.3-34.6)	49.2 (17.9-73.7)	41.5 (11.7-68.5)	38.5 (15.9-59.3)	0.027*
Desaturation Index	5.0 (2.5-39.5)	43.0 (19.7-84.0)	47.9 (18.8-77.3)	56.8 (25.7-74.6)	0.083
Snoring	14.8 (1.4-23.6)	28.7 (10.6-42.0)	26.2 (15.2-35.7)	27.5 (17.6-36.1)	0.050
*Significant at p < 0.05. Only Sleep Efficiency vs Age survives Bonferroni correction (p < 0.002).					

Age-related differences in sleep study parameters are summarized in Table 4. Sleep efficiency showed a significant decline with increasing age (p = 0.005), with the oldest group (≥65 years) exhibiting the lowest median sleep efficiency. AHI values also varied significantly across age groups (p = 0.027), with the highest values observed in the 31–49 age group.

Gender differences in sleep study parameters are presented in Table 5. Males had significantly higher arousal index and snoring intensity compared to females. However, AHI and desaturation index values did not differ significantly between genders.

Finally, the negative binomial GLM regression analysis (Table 6) identified BMI as the only significant independent predictor of AHI. For each 1-unit increase in BMI, the AHI was expected to increase by a factor of 1.024 (p = 0.002), holding other variables constant. Age and gender were not significant predictors in this model.

Discussion

This study presents a comprehensive analysis of the associations between polysomnographic variables and key demographic and anthropometric factors in a cohort of 251 Sudanese adults diagnosed with obstructive sleep apnea (OSA). Using robust non-parametric statistical methods including the Mann-Whitney U test, Kruskal-Wallis test, and Spearman correlation, we ensured valid inference despite the skewed distribution of AHI and related parameters. The negative binomial generalized linear model was particularly suitable, outperforming standard linear regression by addressing violations of normality and homoscedasticity.

Our primary finding is that body mass index (BMI) is the most significant and consistent predictor of OSA severity in this population. This conclusion is supported by both the Kruskal-Wallis test, which revealed a clear dose-response relationship, and the regression model, which identified BMI as the sole significant independent predictor of AHI. The strong association between BMI and AHI (Spearman's rho = 0.307) aligns with extensive international literature that identifies obesity as the primary modifiable risk factor for OSA [16,17]. Notably, each 1-unit increase in BMI was associated with a 2.4% increase in AHI, underscoring the importance of weight management in clinical strategies for OSA in Sudan. The high prevalence of Class III obesity (34.3%) in our cohort further reinforces this point.

Historical and global studies have consistently linked Obstructive sleep apnea-hypopnea syndrome (OSAHS) to excess weight, particularly among middle-aged obese individuals. One study found that a 10% weight gain increased the risk of OSA sixfold [13]. Another reported that moderate to severe OSA (AHI ≥15) was present in 11% of normal-weight men, 21% of overweight men, and 63% of obese men [14]. Similarly, in women, prevalence rates were 3%, 9%, and 22%, respectively [18]. A study by Yalım found

Table 5: Gender Differences in Sleep Study Parameters (Median (IQR))

Parameter	Males (n=134)	Females (n=117)	p-value
Sleep Efficiency	86.0 (77.3-93.1)	78.8 (67.2-89.0)	0.002*
Arousal Index	19.2 (10.5-31.0)	13.3 (6.0-21.7)	<0.001*
AHI	43.9 (22.2-66.9)	33.0 (8.4-65.5)	0.065
Desaturation Index	49.5 (23.0-72.8)	45.4 (13.6-81.4)	0.770
Snoring	28.3 (16.4-40.5)	24.3 (10.8-34.7)	0.016*
*Significant at p < 0.05. Arousal Index and Sleep Efficiency differences survive Bonferroni correction (p < 0.002).			

Table 6: Negative Binomial GLM Results for Predictors of AHI

Predictor	Incidence Rate Ratio (IRR)	95% Confidence Interval	p-value
BMI	1.024	1.009 – 1.039	0.002*
Age	0.999	0.989 – 1.009	0.816
Gender (Male vs. Female)	1.122	0.859 – 1.467	0.399
*Significant at p < 0.05.			

that 42.6% of OSA patients were overweight and 26% had first-degree obesity, with each unit increase in BMI leading to a 1.538-unit rise in AHI [19]. Mechanistically, obesity contributes to pharyngeal airway collapsibility by increasing adipose tissue around the airway and reducing lung volumes due to visceral fat, thereby increasing mechanical loads on the respiratory system [20].

Our analysis also revealed a significant negative correlation between age and sleep efficiency, consistent with known age-related changes in sleep architecture. However, age was not an independent predictor of AHI in our regression model, suggesting that while older individuals may experience poorer sleep quality, OSA severity is more strongly influenced by BMI. Supporting this, Fietze et al.[12] reported that OSA prevalence increases with age in both sexes, though women tend to be diagnosed later. Their study also identified associations between OSA and factors such as gender, age, BMI, waist-to-hip ratio, snoring, alcohol consumption (in women), and cardiovascular diseases, while daytime sleepiness showed no significant link [13].

Gender differences in sleep parameters were also observed. Males exhibited higher arousal indices and snoring intensity, indicating more disrupted sleep [21]. However, AHI values did not differ significantly between genders [22,23]. This challenges the stereotype of OSA as a predominantly male disorder and suggests that females may present with different symptoms—such as fatigue and insomnia—despite having comparable disease severity. This highlights the need for heightened clinical awareness and diagnostic vigilance in women, who may be underdiagnosed [21].

Further, our findings showed significant variations in sleep efficiency, arousal index, and snoring intensity between genders, but no differences in desaturation index or AHI. A meta-analysis exploring sex differences in insomnia risk emphasized the need to understand gender-specific sleep patterns [15]. Women frequently report more sleep disturbances, including insomnia and nightmares, which are twice as common compared to men [23,24]. These discrepancies are often linked to hormonal fluctuations

throughout the menstrual cycle [25,26]. Additionally, modern lifestyle factors—such as increased work demands, psychosocial stress, and additional responsibilities like childcare—may exacerbate sleep deprivation in women. While the adverse effects of sleep restriction are well-documented in men, they remain underexplored in women [27].

Finally, our study demonstrated a positive association between severe OSA and comorbid conditions such as diabetes, hypertension, and metabolic syndrome. Notably, clinical parameters in women showed stronger associations with OSA compared to men. Hongyo et al. also found that OSA severity increases with age, identifying male gender, BMI, and age as independent risk factors for severe OSA in elderly patients [17].

Conclusion

In this cohort of Sudanese adults with OSA, increasing BMI was the most powerful and consistent predictor of OSA severity. Age was primarily associated with a decline in sleep efficiency rather than an increase in AHI. While males exhibited greater sleep fragmentation, OSA severity was comparable between genders, underscoring the importance of diagnosing OSA in females. These findings highlight the critical role of weight management in mitigating OSA severity in the Sudanese population and emphasize the need for nuanced, gender-aware clinical assessments.

Study Limitations

This study has several limitations. Its retrospective, cross-sectional design prevents the establishment of causality. the study did not include other important anthropometric measurements like neck circumference or data on comorbidities such as hypertension and diabetes, which are known confounders. Future research should aim to address these limitations through prospective, community-

based studies that include a wider range of clinical and demographic data.

Funding

Conflict of interest

The authors declare that there is no conflict of interest in this work

Ethical consideration

The data of this work has been taken from the sleep study center, and verbal consent has been taken from all patients who participated in this work. The authors took permission from, the ethical committee in the faculty of medicine at the National University of Africa.

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