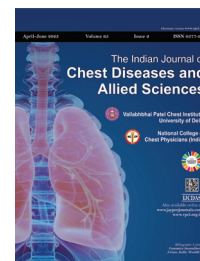


A Study of Sleep Architecture among Sleep Apnea Patients at a Tertiary Care Center: A Retrospective Analysis

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ABSTRACT

Introduction: Sleep is an active biological phenomenon which has subtypes of non-rapid eye movement (NREM) and rapid eye movement (REM) sleep. Sleep cycle, NREM, and REM stages are affected in patients with sleep disorder breathing.

Objectives: To study sleep architecture among sleep apnea patients and compare all parameters in defined subgroups.

Materials and methods: A retrospective analysis of a total of 150 cases (age > 10 years) of sleep apnea was included in our study. The REM-AHI/NREM-AHI ≥ 2 was the criteria stamped as REM-related disorder. Detailed history, anthropometric data, and polysomnography (PSG) parameters were recorded. Continuous positive airway pressure (CPAP) titration was performed among 141 patients.

Results: There were 90 males and 60 females in whom mean (SD) of age, BMI, neck girth, Epworth score, and mean oximetry were 54.35 (14.07), 33.48 (7.40), 39.05 (5.30), 17.32 (3.60) and 85.45 (8.51) respectively. Mean (SD) of PSG parameters like total sleep time (min), sleep efficiency, N1, N2, N3, REM percentage, AHI total, AHI-NREM, AHI-REM, and oxygen desaturation index (ODI) were 381.44 (104.47), 85.17 (14.66), 24.94 (16.01), 50.62 (41.42), 20.08 (14.62), 7.40 (9.01), 46.47 (22.25), 46.83 (22.75), 46.82 (25.76) and 43.17 (28.39). Out of 150, 130 (86.67%) were obese and 15 (10%) had REM-related disorders. Mild, moderate, and severe obstructive sleep apnea (OSA) was detected in 12 (8%), 22 (14.67%), and 116 (77.33%) respectively.

Conclusion: Sleep apnea is having a lower proportion of slow wave, REM sleep, and a higher percentage of light sleep. Obesity is an obvious contributing factor to disturbed sleep architecture. Female sleep apnea patients have less disturbed sleep architecture although REM-related disorder is more observed in females.

Keywords: Non rapid eye movement, Rapid eye movement related, Sleep apnea, Sleep architecture, Slow wave sleep.

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ABBREVIATIONS USED IN THIS ARTICLE

AHI = Apnea-hypopnea index; NREM = Non-rapid eye movement sleep; SWS = Slow wave sleep; REM = Rapid eye movement; PSG = Polysomnography; CPAP = Continuous positive airway pressure; TST = Total sleep time.

INTRODUCTION

Sleep is a vital neurophysiologic phenomenon and an essential biological requirement for human survival, consisting of two stages that alternate during sleep: Non-rapid eye movement sleep (NREM) and rapid eye movement sleep (REM).^{1,2} Non-rapid eye movement sleep is further subdivided into three stages: N1, N2, and slow wave sleep (SWS or N3).³ Sleep is controlled by two independent but interconnected processes: the homeostatic process and the circadian process.^{1,4,5} The circadian drive, which is modulated by the inner mechanism and is synchronized with the cycles of light and darkness, affects sleep tendencies during the 24-hour time span, whereas the homeostatic element signifies the sleep stress accumulated due to alertness and determines the sleep hours and, particularly, the quantity of SWS. Thus, SWS is a homeostatic mechanism that is assumed to reflect the regenerative function of sleep.⁶

Sleep architecture shows how the sleep stages are organized throughout the night (Fig. 1). In a very young adult, the traditional sleep cycle typically begins with a shift from alertness to N1 sleep, followed by a rapid transition to N2 and N3 sleep. The predominant event of paradoxical sleep occurs around 90 minutes; since then,

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throughout the night, every 90–110 minutes, the body alternates between NREM and REM sleep. The N3 sleep typically takes up the first part of the night, with stage R (REM) sleep taking up the second. For the healthy person in their second decade, Stage N1 accounts for 2–5% of total sleep time, stage N2 for 45–55%, stage N3 for 13–23%, and stage R for 20–25%.⁷

The general pattern of sleep architecture is determined by the stages of development and aging. Infants, for example, spend up to

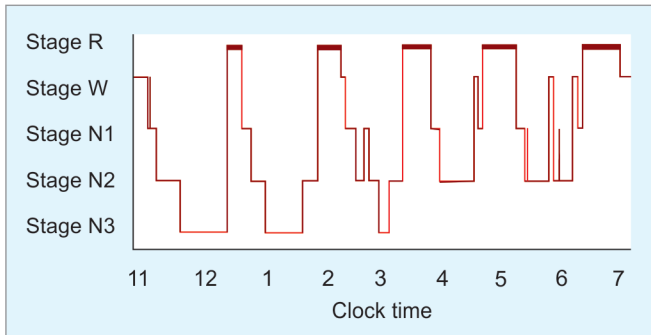


Fig. 1: A typical hypnogram demonstrating normal sleep architecture

half of the night in rapid eye movement sleep and may experience a REM sleep cycle followed by NREM sleep. Most sleep stages vary with age, including diminished total sleep time and sleep efficiency, a rise in the number of stages N1 and N2, a decrease in the proportion of SWS, and paradoxical sleep. These aging-related alterations have been reported to be more significant in males than in females.^{7,8}

Objective tests are used as part of the diagnosis process once a physical examination and history pertaining to sleep are completed. The gold standard for diagnosing obstructive sleep apnea (OSA) is facility-based, attended, overnight polysomnography (PSG) (Level 1 PSG). The apnea-hypopnea index (AHI) is the event of apneic and hypopnea occurrences per hour on average. This index, generated from PSG, is employed not just to identify but also to assess the intensity of OSA. Obstructive sleep apnea is defined as mild, moderate, or severe in accordance with AHI. Apnea-hypopnea index 5–15 episodes per hour of sleep is considered mild; AHI 15–30 episodes per hour of sleep is considered moderate; and AHI >30 episodes per hour of sleep is considered severe.^{9,10}

Although upper airway collapse can happen in both NREM and REM sleep, the decrease in tone during naps additionally diminishes pharyngeal muscular activity, increasing the likelihood of upper airway collapse during this stage of sleep. Thus, compared to NREM, rapid eye movement sleep is linked with a higher risk and frequency of obstructive episodes in patients with OSA. The phrase “REM-related OSA” refers to occurrences that occur mostly or solely during the REM state of sleep.¹¹

The definition of REM-related OSA varies greatly. The following are the most regularly used and widely accepted prerequisites in various research pertinent to REM-related OSA: (REM AHI)/(NREM AHI) ratio ≥ 2 . Along REM AHI > 5 with NREM AHI < 5; and at least 30 minutes of REM sleep.^{11–13} Alternatively, NREM AHI < 15, with at least 30 minutes of REM sleep.

MATERIALS AND METHODS

From April 2019 to July 2021, a retrospective observational investigation was conducted at our institute’s Department of Respiratory Medicine. Patients diagnosed with OSA by overnight level II PSG and continuous positive airway pressure (CPAP) titration aged > 10 years were included in the study. The study excluded pregnant women and those with inconclusive sleep studies. The institutional human ethics panel gave its approval, and the participants’ confidentiality was preserved.

METHODOLOGY

We analyzed 150 patients with OSA. By personally questioning the patients, data on age, gender, BMI, neck girth, presence of

co-morbidities, and Epworth sleepiness scale (ESS) were gathered. Polysomnography was performed on all patients in the in-house quality-controlled level II sleep lab utilizing Philips Respironics ALICE 5 PSG. The PSG variables included average oximetry of awake, NREM, REM stage, and lowest oxygen saturation (SpO_2); limb movement index; sleep stages (N1, N2, N3, and REM); length of sleep as a percentage of total sleep time (TST); and duration. In addition, total apnea-hypopnea index (AHI), REM AHI, NREM AHI, ratio (REM AHI/NREM AHI), oxygen desaturation index, arousal index, sleep latency, and sleep efficiency were also assessed.

Out of 150 patients, 9 were subjected to airway surgery, and 141 were subjected to CPAP titration by using auto CPAP A Flex at 4–20 cm H_2O of pressure. Encore Pro 2 (Respironics, Murrysville, PA, USA) art software version in a sleep lab, auto CPAP was employed with a smart card inserted, and participants underwent auto CPAP titration. Following the titration night, information that had been recorded was downloaded, concluding in the retrieval of the following information: (1) P90—the 90th percentile pressure that the auto CPAP device delivers and which cures snoring, apnea, and flow limitations; (2) the highest pressure (P max); and (3) the mean (P avg) pressure. All data were gathered and analyzed at the conclusion of the study using a very systematic proforma.

Statistical Analysis

Microsoft Excel was used to enter all of the acquired data, and SPSS 20 (Statistical Package for Social Science version) software was used to review it. Continuous variables were summarized as a percentage (%), while categorical parameters were summarized as a mean and variance (SD). A student *t*-test, Chi-square, and mean difference were applied to check different groups.

RESULTS

In Table 1, all the anthropometric, demographic, and PSG details of 150 patients are shown. The male-to-female ratio was 1.5, and also the ESS, lowest SpO_2 (%), and mean SpO_2 (%) were 54.35 (14.07), 33.48 (7.40), 39.05 (5.30), 17.32 (3.60), 71.05 (14.16), and 85.45 (8.51), respectively. The mean (SD) of PSG parameters like TST (minutes), sleep efficiency (%), N1, N2, N3, REM sleep stages (%), AHI-total, AHI-NREM, and AHI-REM (per hour) were 381.44 (104.47), 85.17 (14.66), 24.94 (16.01), 50.62 (41.42), 20.08 (14.62), 7.40 (9.01), 46.74 (22.25), 46.83 (22.75), and 46.82 (25.76), respectively. A CPAP titration was performed among 141 patients who showed a mean \pm SD of residual AHI and a median CPAP value of 5.91 \pm 6.10 and 8.22 \pm 3.23 cm H_2O , respectively.

The comparison of various variables among two gender groups has been demonstrated in Table 2. It shows that variables like age, BMI, neck girth, ESS, TST, AHI, and CPAP pressure were evenly distributed ($p > 0.05$). When compared to male sleep apneics, the oximetry (SpO_2) of awake, NREM, rapid eye movement, and average was considerably lower in females. The alteration in SWS and REM sleep was far more evident in the male group of participants.

Table 3 demonstrates the comparison in step with obesity status. Obesity was defined as a BMI of 25 kg/m².¹⁴ The obese group had a higher age compared to the non-obese group, with a major difference ($p < 0.05$). Sleep efficiency was significantly lower in non-obese, sleep-deprived patients compared to obese ones. In addition, oxygen desaturation and CPAP pressure requirements to eliminate sleep apnea were substantially higher within the obese group of patients than within the non-obese one. Sleep

Table 1: Baseline demographic, anthropometric, and polysomnographic characteristics of all participants

Variables (n = 150)	Mean ± SD
Age (Years)	54.35 ± 14.07
Sex (Male/Female)	90/60 (1.5:1)
Weight (Kg)	86.71 ± 20.38
BMI (Kg/m ²)	33.48 ± 7.40
Neck Girth (cm)	39.05 ± 5.30
ESS	17.32 ± 3.60
Oximetry (SpO ₂) (%)	
Awake	92.64 ± 6.78
NREM	90.60 ± 7.51
REM	87.45 ± 10.39
Lowest	71.05 ± 14.16
Mean SpO ₂	85.45 ± 8.51
TST (minutes)	381.44 ± 104.47
Sleep efficiency (%)	85.17 ± 14.66
Sleep architecture	
NREM 1 (%)	24.94 ± 16.01
NREM 2 (%)	50.62 ± 41.42
NREM 3 (%)	20.08 ± 14.62
REM (%)	7.40 ± 9.01
REM duration (minutes)	26.11 ± 29.81
Apnea index (per hour)	26.25 ± 16.85
Hypopnea index (per hour)	20.49 ± 12.03
AHI NREM (per hour)	46.83 ± 22.75
AHI REM (per hour)	46.82 ± 25.76
AHI over all (per hour)	46.74 ± 22.25
ODI (per hour)	43.17 ± 28.39
PLMI (per hour)	7.76 ± 19.73
CPAP analysis (n = 141)	
Residual AHI (per hour)	5.91 ± 6.10
P90 (cm H ₂ O)	10.33 ± 3.95
Average P (cm H ₂ O)	8.22 ± 3.23
Peak P (cm H ₂ O)	12.84 ± 4.45

AHI, apnea hypopnea index; Avg, average; BMI, body mass index; CPAP, continuous positive airway pressure; ESS, Epworth sleepiness score; NREM, non REM; ODI, oxygen desaturation index; PLMI, periodic leg movement index; P90, pressure of 90th percentile in CPAP; peak P, highest pressure in CPAP titration; REM, rapid eye movement; TST, total sleep time

architecture was more affected in the obese group, characterized by an increased proportion of N1 and a lower proportion of N2, N3, and REM sleep.

It was discovered that REM-related disorders were more frequent in females. Table 4 shows comparisons according to the dominance of REM-related sleep disorders, which demonstrate that the extent of AHI and oxygen desaturation was less affected in REM-related sleep apnea individuals. The residual AHI after CPAP

titration and CPAP pressure requirement had a significantly lower value in predominant paradoxical sleep apnea patients.

In comparison to the mild to moderate category, the incidence of severe OSA was higher. Figure 2 demonstrates the frequency of patients in each severity category (according to AHI) in the subgroups of NREM and REM. Table 5 shows the comparison of all variables among the mild and moderate-to-severe sleep apnea groups. The factors like age, ESS, lowest SpO₂, mean SpO₂, rapid eye movement sleep (%), REM sleep duration, AHI, oxygen desaturation index, and average CPAP requirement were proportionally correlated with the severity of sleep apnea with a considerable difference ($p < 0.05$).

DISCUSSION

According to the study's findings, patients with OSA have more light sleep and less deep sleep than those without apnea. Age and BMI have been found to affect sleep stages N1 and SWS.¹⁵ In our study, N1 sleep is heavily plagued by factors like TST, sleep efficiency, age, and AHI. With an *R*-square value of 0.46, multiple linear correlations reveal a significant ($p < 0.05$) value for every variable influencing the proportion of N1. Slow wave sleep, on the other hand, showed a further correlation with mean SpO₂ and also the periodic leg movement index (PLMI) ($p < 0.05$) (Table 6).

Depending on the defining criteria and population elements, the average incidence of REM-related OSA in research ranges from 10 to 40%.^{16,17} In comparing OSA with regard to the predominance of REM events, variables like age, BMI, neck girth, Epworth score, and sleep efficiency didn't show any significant difference. Several other studies have shown similar results to ours.¹⁷⁻¹⁹ Moreover, AHI and ODI showed significantly lower values within the REM-related OSA group. The mean nadir SpO₂ was lower within the NREM-related OSA group.¹⁹ According to the present study, women were more likely to experience REM-related OSA, with an odds ratio of 3.4 ($p < 0.05$). A similar finding was observed in other studies as well.¹⁶⁻²¹ The odds ratio for REM-related OSA among females was 3.96 in Nair et al.,¹⁶ 2.19 in Juvelekian et al.,¹⁷ 5.5 in Al Oweidat et al.,¹⁸ and 3.0 in Koo et al.²² In our study, the odds ratio for the same was 3.4, which is comparable to reference studies.

Gender influences both normal and sleep-apnea individuals' sleep architecture. As per a study, TST is more common in elderly females (age >55 years) compared to males.²⁰ Females have a higher percentage of SWS, leg movement disorder, REM-related OSA, and partial airway obstruction. While parameters like AHI, N1 (%) stage, and CPAP requirement showed lower values within the female group of patients, our study also reveals similar findings.

Obesity remarkably changes the sleep architecture. In our study, it was observed that obese individuals had higher values of Epworth score, neck circumference, total AHI, NREM-AHI, REM-AHI, ODI, and PLM Index, which is analogous to Chierakul et al.²³ As depicted in the study, lower rapid eye movement duration and short sleep are established factors for obesity. Within the present study, we also confirmed the identical findings.²⁴

As was observed during a previous study, the severity of OSA progression directly affects the N3 stage percentage.²⁵ Furthermore, consistent with the literature, OSA reduces the N3% stage, sleep efficiency, and REM sleep percentage, and increases N1% and sleep arousals.²⁶ There are only a few studies available that have described and compared sleep architecture consistent with the severity of sleep apnea. In our study, N1% was higher in

Table 2: A comparison of the study population according to gender status

Variables	Male (n = 90)	Female (n = 60)	p-value
Age (Years)	52.59 ± 14.72	57.00 ± 12.69	0.21
Weight (Kg)	87.03 ± 20.32	86.23 ± 20.63	0.84
Height (cm)	163.58 ± 10.30	156.20 ± 8.48	0.51
BMI (Kg/m ²)	32.32 ± 6.80	35.23 ± 7.96	0.21
Neck girth (cm)	39.01 ± 5.27	39.12 ± 5.40	0.72
ESS	17.34 ± 3.76	17.28 ± 3.37	0.31
Oximetry (SpO ₂) (%)			
Awake	94.02 ± 3.71	90.57 ± 9.39	<0.001
NREM	91.96 ± 5.43	88.57 ± 9.53	0.001
REM	88.74 ± 8.79	85.50 ± 12.23	0.025
Lowest	73.19 ± 13.38	67.85 ± 15.87	0.09
Mean	86.99 ± 6.67	83.13 ± 10.33	0.001
TST (min)	383.59 ± 109.59	378.22 ± 97.10	0.54
Sleep efficiency	83.82 ± 16.29	87.20 ± 11.62	0.12
Sleep architecture			
NREM 1 (%)	27.63 ± 15.58	20.91 ± 15.94	0.28
NREM 2 (%)	53.09 ± 51.89	46.92 ± 15.78	0.32
NREM 3 (%)	18.08 ± 11.95	23.07 ± 17.59	0.01
REM (%)	6.26 ± 6.92	9.11 ± 11.29	0.001
REM duration (minutes)	22.54 ± 22.69	31.45 ± 37.67	0.001
Apnea index (per hour)	26.92 ± 17.91	25.25 ± 15.22	0.4
Hypopnea index (per hour)	19.45 ± 12.12	22.04 ± 11.81	0.92
AHI NREM (per hour)	46.57 ± 23.52	47.21 ± 21.73	0.73
AHI REM (per hour)	43.88 ± 26.77	51.22 ± 23.70	0.22
AHI overall (per hour)	46.83 ± 23.33	47.21 ± 20.71	0.59
ODI (per hour)	40.94 ± 27.15	46.50 ± 30.07	0.25
PLMI (per hour)	6.47 ± 16.63	9.73 ± 23.72	0.19
CPAP analysis (n = 141)	n = 84	n = 57	
Residual AHI per hour	6.38 ± 6.48	5.18 ± 5.42	0.2
P90 (cm H ₂ O)	10.60 ± 4.08	9.92 ± 3.75	0.62
Average P (cm H ₂ O)	8.45 ± 3.43	7.87 ± 2.95	0.41
Peak P (cm H ₂ O)	12.76 ± 4.57	12.95 ± 4.29	0.7

AHI, apnea hypopnea Index; BMI, body mass index; CPAP, continuous positive airway pressure; ESS, Epworth sleepiness score; NREM, non REM; ODI, oxygen desaturation index; PLMI, periodic leg movement index; P90, pressure of 90th percentile in CPAP; peak P, highest pressure in CPAP titration; REM, rapid eye movement; TST, total sleep time

Table 3: A comparison of the study population according to the severity of obesity

Variables	Obese (n = 130)	Non obese (n = 20)	p-value
Age (Years)	55.99 ± 0.98	43.70 ± 23.69	<0.001
Sex (Male/Female)	75/55	15/5	0.14
Weight (Kg)	91.92 ± 1534	52.85 ± 16.36	0.59
Height (cm)	161.47 ± 8.36	155.15 ± 17.66	<0.001
BMI (Kg/m ²)	35.34 ± 5.93	21.39 ± 3.60	0.6
Neck girth (cm)	40.24 ± 4.27	31.35 ± 4.97	0.27
ESS	18.01 ± 3.08	12.85 ± 3.56	0.15
Oximetry (SpO ₂) (%)			
Awake	92.13 ± 7.08	95.95 ± 2.72	0.06
NREM	89.98 ± 7.74	94.60 ± 3.97	0.1
REM	86.71 ± 10.79	92.25 ± 5.26	0.1
Lowest	69.50 ± 14.34	81.15 ± 12.45	0.36
Mean	84.60 ± 8.58	90.95 ± 5.57	0.16
TST (min)	379.84 ± 102.81	391.85 ± 117.03	0.9
Sleep efficiency	86.12 ± 13.72	79.00 ± 19.01	0.03
Sleep architecture			
NREM 1 (%)	25.40 ± 15.46	21.98 ± 19.48	0.04
NREM 2 (%)	50.03 ± 43.68	54.48 ± 22.06	0.71
NREM 3 (%)	20.94 ± 14.59	14.48 ± 13.89	0.55
REM (%)	7.14 ± 8.99	9.06 ± 9.18	0.97
REM duration (minutes)	25.34 ± 30.29	31.06 ± 26.69	0.72
Apnea index (per hour)	26.44 ± 16.68	25.07 ± 18.38	0.51
Hypopnea index (per hour)	21.92 ± 11.85	11.20 ± 8.70	0.18
AHI NREM (per hour)	48.61 ± 22.40	35.21 ± 22.03	0.96
AHI REM (per hour)	48.32 ± 25.68	37.05 ± 24.70	0.86
AHI overall (per hour)	48.63 ± 21.97	36.26 ± 21.56	0.92
ODI (per hour)	45.72 ± 28.59	26.55 ± 20.78	0.047
PLMI (per hour)	8.44 ± 21.03	3.38 ± 5.43	0.13
CPAP Analysis (n = 141)	n = 129	n = 12	
Residual AHI per hour	6.26 ± 5.71	3.60 ± 7.92	0.82
P90 (cm H ₂ O)	11.02 ± 3.24	5.84 ± 5.15	<0.001
Average P (cm H ₂ O)	8.78 ± 2.73	4.60 ± 4.02	<0.001
Peak P (cm H ₂ O)	13.68 ± 3.36	7.38 ± 6.46	<0.001

AHI, apnea hypopnea index; BMI, body mass index; CPAP, continuous positive airway pressure; ESS, Epworth sleepiness score; NREM, non REM; ODI, oxygen desaturation index; PLMI, periodic leg movement index; P90, pressure of 90th percentile in CPAP; peak P, highest pressure in CPAP titration; REM, rapid eye movement; TST, total sleep time

Table 4: A comparison according to the category of predominant REM sleep apnea

Variables	REM predominant sleep apnea		p-value
	Yes (n = 15)	No (n = 135)	
Age (years)	56.07 ± 8.91	54.16 ± 14.54	0.09
Sex (Male/Female)	05/10	85/50	0.02
Weight (Kg)	89.80 ± 19.54	86.37 ± 20.52	0.93
Height (cm)	159.27 ± 9.99	160.78 ± 10.30	0.83
BMI (Kg/m ²)	35.92 ± 9.42	33.21 ± 7.13	0.13
Neck girth (cm)	37.93 ± 4.80	39.18 ± 5.36	0.7
ESS	14.80 ± 2.60	17.60 ± 3.59	0.16
Oximetry (SpO ₂) (%)			
Awake	92.07 ± 10.49	92.70 ± 6.29	0.41
NREM	91.53 ± 9.28	90.50 ± 7.31	0.9
REM	86.27 ± 18.57	87.58 ± 9.16	0.007
Lowest	76.40 ± 9.86	70.46 ± 14.96	0.06
Mean	86.60 ± 10.36	85.32 ± 8.31	0.69
TST (min)	338.47 ± 103.63	386.21 ± 103.84	0.69
Sleep efficiency	80.62 ± 14.18	85.68 ± 14.67	0.83
Sleep architecture			
NREM 1 (%)	13.95 ± 20.01	26.16 ± 15.11	0.17
NREM 2 (%)	45.07 ± 17.39	51.24 ± 43.28	0.85
NREM 3 (%)	19.94 ± 19.85	20.09 ± 14.01	0.06
REM (%)	21.05 ± 12.98	5.88 ± 7.03	<0.001
REM duration (minutes)	68.53 ± 46.01	21.39 ± 23.31	0.001
Apnea index (per hour)	10.17 ± 6.88	28.04 ± 16.70	0.005
Hypopnea index (per hour)	11.23 ± 5.71	21.52 ± 12.12	0.006
AHI NREM (per hour)	17.95 ± 10.37	50.03 ± 21.45	0.03
AHI REM (per hour)	48.35 ± 23.47	46.65 ± 26.08	0.58
AHI overall (per hour)	21.39 ± 10.24	49.83 ± 21.04	0.02
ODI (per hour)	28.27 ± 20.83	44.82 ± 28.69	0.02
PLMI (per hour)	7.13 ± 7.34	7.84 ± 20.68	0.46
CPAP Analysis (n = 141)	n = 14	n = 127	
Residual AHI per hour	3.31 ± 2.07	6.20 ± 6.33	0.02
P90 (cm H ₂ O)	8.79 ± 3.20	10.50 ± 3.99	0.43
Average P (cm H ₂ O)	6.87 ± 2.63	8.37 ± 3.29	0.42
Peak P (cm H ₂ O)	12.36 ± 2.92	12.88 ± 4.58	0.29

AHI, apnea hypopnea index; BMI, body mass index; CPAP, continuous positive airway pressure; ESS, Epworth sleepiness score; NREM, non REM; ODI, oxygen desaturation index; PLMI, periodic leg movement index; P90, pressure of 90th percentile in CPAP; peak P, highest pressure in CPAP titration; REM, rapid eye movement; TST, total sleep time

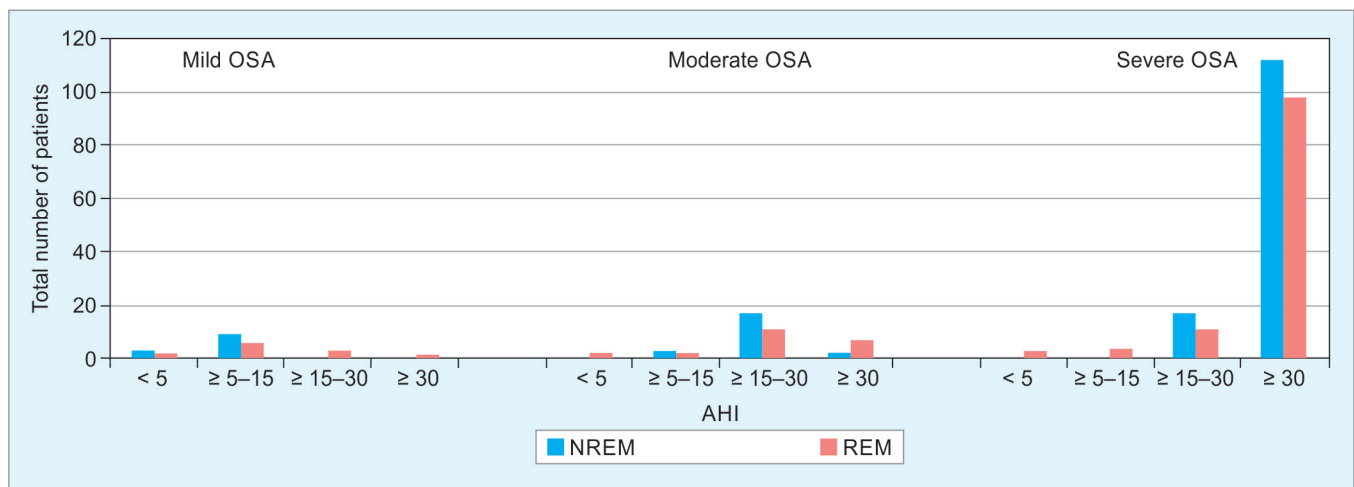


Fig. 2: A diagram showing the magnitude of NREM and REM sleep apnea in various categories of OSA severity
AHI, apnea-hypopnea index; NREM, non REM; REM, rapid Eye Movement; OSA, obstructive sleep apnea

Table 5: A comparison of different variables according to the severity of sleep apnea

Variables	Mild (n = 12)	Moderate to severe (n = 138)	p-value
Age (years)	44.5 ± 17.91	55.21 ± 13.42	0.01
Male/Female	09/03	81/57	0.27
Weight (Kg)	81.83 ± 30.82	87.14 ± 19.32	0.4
Height (cm)	160.42 ± 17.23	160.71 ± 10.22	0.94
BMI (Kg/m ²)	31.40 ± 10.70	33.66 ± 7.06	0.31
Neck girth (cm)	36.42 ± 6.30	39.28 ± 5.17	0.07
ESS	13.17 ± 4.20	17.68 ± 3.32	<0.001
Oximetry (SpO ₂) (%)			
Awake	94.83 ± 3.61	92.45 ± 6.97	0.25
NREM	94.08 ± 3.58	90.30 ± 7.69	0.09
REM	91.00 ± 5.38	87.14 ± 10.67	0.22
Lowest	81.75 ± 10.54	70.12 ± 14.58	0.008
Mean	90.42 ± 5.15	85.02 ± 8.63	0.04
TST (min)	336.79 ± 105.95	385.33 ± 103.82	0.12
Sleep efficiency	81.30 ± 12.33	85.51 ± 14.83	0.34
Sleep architecture			
NREM 1 (%)	19.58 ± 16.79	25.41 ± 15.93	0.23
NREM 2 (%)	42.00 ± 11.62	51.37 ± 42.99	0.45
NREM 3 (%)	23.65 ± 19.14	19.76 ± 14.21	0.38
REM (%)	14.80 ± 13.20	6.76 ± 8.30	0.003
REM duration (minutes)	49.33 ± 44.98	24.10 ± 27.44	0.005
Apnea index (per hour)	3.86 ± 1.88	28.20 ± 16.15	<0.001
Hypopnea index (per hour)	4.49 ± 3.34	21.88 ± 11.49	<0.001
AHI NREM (per hour)	7.04 ± 3.46	50.28 ± 20.27	<0.001
AHI REM (per hour)	14.90 ± 15.56	49.59 ± 24.60	<0.001
AHI overall (per hour)	8.35 ± 3.09	50.34 ± 22.25	<0.001
ODI (per hour)	14.08 ± 9.51	45.70 ± 28.08	<0.001
PLMI (per hour)	7.07 ± 9.67	7.82 ± 20.40	0.9
CPAP Analysis (n = 141)	n = 9	n = 132	
Residual AHI per hour	2.93 ± 4.72	6.17 ± 6.15	0.08
P90 (cm H ₂ O)	6.98 ± 4.71	10.62 ± 3.76	0.002
Average P (cm H ₂ O)	5.54 ± 3.71	8.45 ± 3.12	0.003
Peak P (cm H ₂ O)	9.10 ± 5.73	13.07 ± 4.32	0.02

AHI, apnea hypopnea index; BMI, body mass index; CPAP, continuous positive airway pressure; ESS, Epworth sleepiness score; NREM, non REM; ODI, oxygen desaturation index; PLMI, periodic leg movement index; P90, pressure of 90th percentile in CPAP; peak P, highest pressure in CPAP titration; REM, rapid eye movement; TST, total sleep time

Table 6: Stepwise linear regression is used to evaluate the dependability of variables affecting the N1 and N3 stages

Variables	Beta value	p-value	R-square value
N1%			
TST (min)	0.022	0.008	0.46
Sleep efficiency	-0.045	<0.0001	
Age	0.163	0.033	
AHI	0.203	0.008	
N3% (SWS)			
N1%	-0.377	<0.0001	0.49
Mean SpO ₂	-0.295	<0.0001	
PLM index	-0.135	0.043	

AHI, apnea hypopnea index; PLMI, periodic leg movement index; SWS, slow wave sleep; TST, total sleep time

the severe sleep apneic group, with a lower proportion of N3%. The REM sleep percentage and duration even have significantly lower values within the severe OSA group.

CONCLUSION

In sleep apnea, there is a substantially greater percentage of light sleep and a reduced proportion of slow wave sleep and REM sleep, especially in the male group of patients. NREM-related sleep disorders are proportionally more associated with desaturation. Sleep architecture significantly deteriorates in sleep apneic individuals, although age and obesity are major confounders.

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