Original Article

Comparing the characteristics of positional and nonpositional sleep apnea patients among the Jordanian population

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Abstract:

BACKGROUND: Obstructive sleep apnea (OSA) is a common cause of sleep-disordered breathing with a large proportion of the patients exhibiting positional OSA (POSA). In this study, we aimed to evaluate the differences in the demographics, comorbidities, and polysomnographic features between POSA and non-POSA (NPOSA) in a Jordanian sample to further discern the propulsive elements for each group.

METHODS: In this study, we evaluated 1037 adult patients with OSA. POSA was defined as an overall apnea and hypopnea index (AHI) >5, an overall AHI severity at least 1.4 times the nonsupine severity (overall/NS-AHI), and a minimum amount of time (i.e., 20 min) in the supine and nonsupine positions. To compare the clinical characteristics between POSA and NPOSA patients, statistical analyses were performed.

RESULTS: The prevalence of POSA was 41.7%. In comparison to NPOSA patients, POSA patients had higher female sex prevalence, milder OSA, lower body mass index, lower hypertension prevalence, and lower hemoglobin A1C levels compared to NPOSA patients. Moreover, sleep efficiency, total sleep time, and supine sleep time were significantly higher in POSA patients. Nonsupine sleep time, total AHI, rapid eye movement (REM) AHI, non-REM (NREM) AHI, supine AHI, nonsupine AHI, left and right AHI, mean oxyhemoglobin saturation (SpO_2) awake, mean REM and NREM SpO_2, SpO_2 nadir, and time SpO_2 below 90% were significantly lower among POSA patients. The multivariate regression analysis showed that only female gender and hypertension were significantly associated with POSA.

CONCLUSION: POSA is common among OSA patients and demonstrates different clinical characteristics in comparison to NPOSA. Future prospective studies are needed to better characterize the POSA patients and investigate the benefit of positional therapy.

Keywords:

Human, obstructive sleep apnea, positional obstructive sleep apnea, sleep

Even though obstructive sleep apnea (OSA) imposes a substantial health burden through its resultant morbidity and mortality, effective treatment regimens are available and are continuously evolving.[1] Nonetheless, it is crucially to differentiate between positional OSA (POSA) and non-POSA (NPOSA) as the type of OSA considerably alters the selected treatment regimen since patients with POSA significantly benefit from positional therapy (PT).[2] POSA is generally defined as the presence of at least double the frequency of apnea and hypopnea index (AHI) that occur during sleep in the

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supine position in comparison to the lateral position and accounts for approximately 56%–87% of all OSA cases depending on the severity.[3] On the other hand, NPOSA is defined as breathing abnormalities that occur during all sleeping positions.[3]

Patients who have POSA, also known as positional patients (PPs), were reported to be of a younger age, have a lower snoring frequency and a lower body mass index (BMI), and have a milder form of OSA in comparison to patients with NPOSA, also known as non-PPs (NPPs).[2] PT, which mainly involves the avoidance of sleeping in the supine position through the utilization of various methods such as PT devices, has proved to be a relatively cost-effective and clinically efficacious treatment for PPs as their breathing abnormalities predominantly occur in the supine position.[1] Whereas, continuous positive airway pressure (CPAP) is the mainstay therapy for NPPs principally due to the occurrence of breathing abnormalities in the lateral position during sleep.[1] Interestingly, it has been demonstrated that a profoundly dynamic shift between POSA and NPOSA is probable, notably in the context of weight modification as PPs can potentially shift into NPPs by gaining weight. In contrast to that, considerable weight loss has demonstrated the potential shift from NPPs into PPs.[4] This has been postulated to have a remarkable impact in modifying the treatment approach when intolerance to CPAP is compelling in NPPs.[1] Nevertheless, there remains to be a profound lack of thorough understanding of the risk factors that incite the development of either POSA or NPOSA, which in return would undoubtedly influence the development of potential therapies.

Accordingly, due to significant predominance of POSA and the substantial difference in managing patients with POSA in comparison to NPOSA, it is crucial to investigate the differences between the two groups to effectively and efficiently optimize care. In this study, we aimed to evaluate the differences of demographic, comorbidities, and polysomnographic features between both groups in a Jordanian sample to further discern the propulsive elements for POSA and NPOSA.

Methods

We complied to the Strengthening the Reporting of Observational Studies in Epidemiology in conducting this study.[5]

Patients

Based on the hospital chart review, a total number of 1092 (total referred) patients were referred to the sleep laboratory at the JUH between June 2016 and March 2022. The indication for their referral was clinical suspicion of OSA suggested by symptoms such as snoring, increased daytime sleepiness, witnessed apnea, and early morning headache in addition to the preoperative evaluation of surgical patients with suspicion of OSA. Only patients who had an AHI >5 were diagnosed to have OSA and were included in this study; accordingly, 55 patients were excluded.

Measurements

The overnight study consisted of continuous recordings of an electrocardiographic lead, right and left electrooculographic leads, submental, and two electroencephalographic leads. Respiration was monitored throughout the night with thermocouples at the nose and mouth and with thoracic and abdominal strain gauges. Recording of the oxyhemoglobin saturation (SaO_2) and duration of saturation below 90% SpO_2 (minutes) was obtained. The biophysiological changes on the polysomnography (PSG) device were evaluated using the 2.4 version of the American Academy of Sleep Medicine Manual for the Scoring of Sleep and Associated Events.[6] Apnea was defined as a reduction in airflow by >90% with a duration of at least 10 s in which there was a persistent respiratory effect. Hypopnea was defined as a reduction of more than 30% in the airflow that was associated with an electroencephalographic arousal or a 3% or more drop in the SaO_2. The AHI was calculated as the total number of apneas and hypopneas per hour of total sleep time. Sleep state-dependent indices (i.e., nonrapid eye movement AHI [NREM-AHI] and REM-AHI) were also determined by dividing the number of events in NREM and REM sleep by the amount of NREM and REM time, respectively. POSA was defined as the overall AHI >5, the overall AHI severity of at least 1.4 times the nonsupine severity (Overall/NS-AHI), and a minimum amount of time (i.e., 20 min) in the supine and nonsupine positions. This definition provided the most consistent detection of those most likely to demonstrate important reductions in sleep-disordered breathing severity if supine sleep is avoided;[7] NPOSA was defined as the overall AHI severity <1.4 times the non-NS (Overall/NS-AHI) and minimum amount of time (i.e., 20 min) in the supine and nonsupine positions. Total snoring time was recorded throughout the study. The OSA severity was classified as AHI = 5–15, mild OSA; AHI = 15–30, moderate OSA; and AHI >30, severe OSA.[8] The following demographic information was obtained: age, gender, BMI, hypertension, diabetes, heart failure, thyroid diseases, Vitamin D deficiency, hemoglobin status (normal or anemic), thyroid status (hypothyroidism, euthyroid, and hyperthyroidism), creatinine, hemoglobin A1C ($HbA1_C$), Vitamin D, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), ferritin, white blood cell (WBC), thyroid-stimulating hormone (TSH), and thyroxine. Daytime sleepiness was assessed by a translated Arabic version of the Epworth Sleepiness Scale (ESS) completed

by the patient himself/herself.[9] The Arabic version of the ESS we used in our study was validated by Ahmed *et al*. and showed a good internal consistency with a Cronbach's alpha coefficient of 0.89.[10]

Comparison of patients' characteristics between the two groups, POSA and NPOSA was done. We compared patients' demographics, sleep efficiency, total sleep time, nonsupine time, supine time, REM time, nonsupine events, total AHI, REM-AHI, NREM-AHI, supine AHI, and nonsupine AHI. Supine/nonsupine AHI, left AHI, right AHI, arousal index, snoring time, snoring of sleep%, mean SpO_2 awake, mean SpO_2 NREM, mean SpO_2 REM, SpO_2 nadir, and time below 90% SpO_2.

Data analysis

The patients' data were entered into Microsoft Office Excel 2019 and then imported into IBM SPSS v. 25 software to conduct the analysis. Continuous variables were summarized as median and interquartile range (IQR), while categorical variables were summarized as counts and percentages. The comparison in categorical variables between POSA and NPOSA patients was done using the Chi-square test. Whereas, the differences in continuous variables between the two groups were examined using *t*-test. Demographic variables that were significantly different between the two groups were reexamined using multivariate binary logistic regression analysis. $P < 0.05$ was considered statistically significant across all the tests.

Results

Characteristics of the included patients

The medical records of 1037 patients who underwent PSG at our hospital were retrieved. Male composed 52.3% (540/1037) of the included patients. Table 1 describes the characteristics of the included patients. The median and IQR for age and BMI of the study population was 64.00[11] and 37.00,[9] respectively. Furthermore, 61.1% of the patients had hypertension, whereas 44.8% had diabetes. The percentages of heart failure and thyroid diseases among the included patients were 10.7% and 11.2%, respectively. The median and IQR for $HbA1_C$ of the included patients were 6.20,[2] and the median and IQR for creatinine were 0.86.[1] Moreover, 41.7% of the patients had POSA, whereas the rest (58.3%) had NPOSA. In addition, 22.6% of the patients had mild OSA, 15.0% had moderate OSA, and 62.4% had severe OSA.

Table 1: The general demographics of the participants

Variable	Response	Frequency (%)
Sex	Male	540 (52.3)
	Female	493 (47.7)
Hypertension	No	393 (38.9)
	Yes	617 (61.1)
Diabetes mellitus	No	558 (55.2)
	Yes	452 (44.8)
Heart failure	No	902 (89.3)
	Yes	108 (10.7)
Thyroid diseases	No	897 (88.8)
	Yes	113 (11.2)
Vitamin D deficiency	Normal	488 (46.9)
	Deficient	116 (11.1)
Hemoglobin	Normal	356 (34.2)
	Anemic	144 (13.8)
Thyroid status	Hypothyroidism	26 (2.5)
	Euthyroid	711 (68.3)
	Hyperthyroidism	36 (3.5)
Type of OSA	NPOSA	602 (58.3)
	POSA	431 (41.7)
OSA severity	Mild	233 (22.6)
	Moderate	155 (15.0)
	Severe	645 (62.4)
Age (years), median (IQR)		64.00 (18)
Creatinine (mg/dl), median (IQR)		0.86 (1)
HbA1C, median (IQR)		6.20 (2)
Vitamin D (ng/ml), median (IQR)		31.20 (19)
ESR, median (IQR)		30.00 (48)
CRP (mg/l), median (IQR)		8.30 (24)
Ferritin (ng/ml), median (IQR)		48.80 (78)
WBC, median (IQR)		8.54 (3)
TSH (mIU/L), median (IQR)		1.73 (1)
Thyroxine (mcg/dL), median (IQR)		13.58 (3)
BMI, median (IQR)		37.00 (9)

IQR=Interquartile range, ESR=Erythrocyte sedimentation rate, CRP=C-reactive protein, WBC=White blood cells, TSH=Thyroid-stimulating hormone, BMI=Body mass index, OSA=Obstructive sleep apnea, POSA=Positional OSA, NPOSA=Non-POSA, HbA1C=Glycated hemoglobin

Comparison in the demographics between positional obstructive sleep apnea and nonpositional obstructive sleep apnea

The comparison between POSA and NPOSA patients in terms of general demographics showed that sex distribution was significantly different between POSA and NPOSA patients ($P = 0.010$) as females accounted for 52.4% of the POSA patients and 44.4% of the NPOSA patients. NPOSA patients had a significantly higher BMI (37.44 ± 7.82) compared to POSA patients (36.16 ± 8.39) ($P = 0.012$). Furthermore, the percentage of hypertension was significantly lower among POSA patients (44.9%) compared to NPOSA patients (65.4%). On the other hand, the frequency of diabetes, heart failure, thyroid diseases, Vitamin D deficiency, anemia, and thyroid status were not significantly different between POSA and NPOSA patients. In addition, the mean $HbA1_C$ was significantly different between POSA and NPOSA patients ($P = 0.015$) as the mean $HbA1_C$ of NPOSA patients (6.73 ± 1.69) was significantly higher compared to POSA patients (6.44 ± 1.41). However, the mean levels of creatinine, Vitamin D, ESR, CRP, ferritin, WBC, TSH,

and thyroxine were not significantly different between POSA and NPOSA patients [Table 2].

Comparison of polysomnography data between positional obstructive sleep apnea and nonpositional obstructive sleep apnea

Regarding PSG data, OSA severity was significantly different between the POSA and NPOSA groups ($P < 0.001$). Patients with POSA had a significantly lower percentage of severe OSA (55.0%) compared to NPOSA patients (67.8%). Sleep efficiency was significantly higher among the POSA group (77.65 ± 16.95) than the NPOSA one (74.08 ± 17.00) ($P = 0.001$). Furthermore, total sleep time was significantly ($P = 0.001$) higher among POSA patients (333.97 ± 86.71) than NPOSA patients (315.83 ± 83.41). Nonsupine time was significantly ($P < 0.001$) lower among POSA patients (65.14 ± 86.90) than NPOSA patients (143.71 ± 94.05). On the other hand, supine time was significantly ($P < 0.001$) higher among POSA patients (269.64 ± 103.29) compared to NPOSA patients (171.71 ± 103.48). Furthermore, nonsupine events were significantly different between the two groups ($P = 0.00$) as nonsupine events were lower among the POSA group (8.04 ± 15.97) compared to the NPOSA one (105.28 ± 103.43). Moreover, total AHI, REM-AHI, NREM-AHI, nonsupine AHI, supine AHI, left AHI, and right AHI were significantly lower among POSA patients than NPOSA patients. Arousal index was significantly different between the two groups as it was lower among the POSA group (36.16 ± 23.34) in comparison to NPOSA one (43.01 ± 23.29). Moreover, the mean SpO_2 in awake status was significantly ($P < 0.001$) higher among POSA patients (92.44 ± 4.01) than NPOSA patients (91.50 ± 3.99). The mean SpO_2 in NREM was significantly ($P < 0.001$) higher among POSA patients (92.44 ± 4.01) than NPOSA patients (89.12 ± 5.58). Furthermore, the mean SpO_2 in REM was significantly higher among POSA patients (88.64 ± 7.71) than NPOSA patients (86.38 ± 8.30). In addition, SpO_2 nadir was significantly different between the two groups ($P = 0.001$) as it was higher among the POSA group (74.36 ± 13.70) than the NPOSA one (71.35 ± 15.03). Time SpO_2 below 90% was significantly ($P < 0.001$) lower among POSA patients (25.70 ± 31.48) than NPOSA patients (34.78 ± 32.88) [Table 3].

Multivariate regression analysis for the association between demographics and positional obstructive sleep apnea

The multivariate logistic regression analysis showed that only gender and BMI were significantly associated with POSA [Table 4]. Female gender had significantly higher odds for POSA (adjusted odd ratio [AOR] = 1.444; 95% confidence interval [CI]: 1.059–1.971). Moreover, patients with hypertension had significantly lower odds for POSA (AOR = 0.583; 95% CI: 0.419–0.810).

Table 2: Differences in the demographics between positional obstructive sleep apnea and nonpositional obstructive sleep apnea

Variable	NPOSA (*n*=602)	POSA (*n*=431)	*P*
Gender			
Male	335 (55.6)	205 (47.6)	0.010
Female	267 (44.4)	226 (52.4)	
Age	57.67±13.07	56.11±14.31	0.083
Hypertension			
Yes	385 (65.4)	189 (44.9)	0.001
No	204 (34.6)	232 (55.1)	
Diabetes			
No	311 (52.8)	247 (58.7)	0.064
Yes	278 (47.2)	174 (41.3)	
Heart failure			
No	521 (88.5)	381 (90.5)	0.300
Yes	68 (11.5)	40 (9.5)	
Thyroid diseases			
No	520 (88.3)	377 (89.5)	0.530
Yes	69 (11.7)	44 (10.5)	
Vitamin D deficiency			
Normal	270 (80.6)	218 (81.0)	0.891
Deficient	65 (19.4)	51 (19.1)	
Hemoglobin status			
Normal	196 (70.0)	160 (72.7)	0.504
Anemic	84 (30.0)	60 (27.3)	
Thyroid status			
Hypothyroidism	15 (3.5)	11 (3.2)	0.793
Euthyroid	395 (91.4)	316 (92.7)	
Hyperthyroidism	22 (5.1)	14 (4.1)	
Creatinine (mg/dl)	1.10±2.17	1.09±3.30	0.940
HbA1C	6.73±1.69	6.44±1.41	0.015
Vitamin D (ng/ml)	26.51±15.96	26.98±15.68	0.715
ESR	34.23±25.04	35.19±28.44	0.684
CRP (mg/l)	26.74±59.24	21.19±38.75	0.209
Ferritin (ng/ml)	113.81±222.32	117.15±348.34	0.897
WBC	8.57±3.07	9.00±3.94	0.191
TSH (mIU/L)	2.30±4.12	62.47±111.756	0.318
Thyroxine (mcg/dL)	14.22±2.75	14.45±3.33	0.325
BMI	37.44±7.82	36.16±8.39	0.012

ESR=Erythrocyte sedimentation rate, CRP=C-reactive protein, WBC=White blood cells, TSH=Thyroid-stimulating hormone, BMI=Body mass index, POSA=Positional obstructive sleep apnea, NPOSA=Non-POSA, HbA1C=Glycated hemoglobin

Discussion

OSA is a common sleep breathing disorder.[12] A main domain in this disorder is POSA which affects a large proportion of patients with OSA.[7] This study aimed to investigate the prevalence of POSA among OSA patients when evaluating the differences between NPOSA and POSA patients regarding demographics, comorbidities, and polysomnographic characteristics.

Table 3: Comparison in polysomnography data between positional obstructive sleep apnea and nonpositional obstructive sleep apnea patients

Variable	NPOSA (*n*=602)	POSA (*n*=431)	*P*
OSA severity			
Mild	112 (18.6)	121 (28.1)	0.000
Moderate	82 (13.6)	73 (16.9)	
Severe	408 (67.8)	237 (55.0)	
Epworth Sleepiness Scale	10.62±6.36	10.15±6.379	0.243
Sleep efficiency	74.08±17.00	77.65±16.95	0.001
Total sleep time (min)	315.83±83.41	333.97±86.71	0.001
Nonsupine time (min)	143.71±94.05	65.14±86.90	0.000
Supine time (min)	171.71±103.48	269.64±103.29	0.000
REM time (min)	30.95±26.59	34.29±28.94	0.055
Nonsupine events	105.28±103.43	8.04±15.97	0.000
Total AHI	49.06±31.71	38.75±29.79	0.000
REM-AHI	47.13±29.78	41.44±30.99	0.009
NREM-AHI	48.42±32.35	37.83±30.30	0.000
Supine AHI	53.97±35.06	44.81±30.72	0.000
Nonsupine AHI	48.76±37.93	4.40±8.29	0.000
Left AHI	47.14±36.80	9.33±14.84	0.000
Right AHI	48.24±36.24	8.17±12.46	0.000
Arousal index	43.01±23.29	36.16±23.34	0.000
Snoring time (min)	67.58±64.83	67.03±71.61	0.901
Snoring of sleep (%)	21.79±20.17	20.00±20.47	0.164
Mean SpO2 awake	91.50±3.99	92.44±4.01	0.000
Mean SpO2 NREM	89.12±5.58	90.42±5.58	0.000
Mean SpO2 REM	86.38±8.30	88.64±7.71	0.000
SpO2 Nadir	71.35±15.03	74.36±13.70	0.001
Time SpO2 below 90% (min)	34.78±32.88	25.70±31.48	0.000

OSA=Obstructive sleep apnea, POSA=Positional OSA, NPOSA=Non-POSA, REM=Rapid eye movement, NREM=Non-REM, AHI=Apnea and hypopnea index, SpO2=Oxygen saturation

Table 4: Multivariate regression analysis for the demographics associated with positional obstructive sleep apnea

Variable	Response	AOR (95% CI)	*P*
Gender	Female	1.444 (1.059-1.971)	0.020*
BMI	-	0.982 (0.963-1.001)	0.067
Hypertension	Yes	0.583 (0.419-0.810)	0.001*
HbA1C	-	0.935 (0.842-1.037)	0.204

**P*<0.05. AOR=Adjusted odds ratio, HbA1C=Glycated hemoglobin, BMI=Body mass index, CI=Confidence interval

The prevalence of POSA among OSA patients in our study was 41.7%, which is lower than the previously estimated prevalence. Previous studies showed that the prevalence in the literature varies between 56% and 74%.[11,13-15] The diversity in the literature regarding the prevalence of POSA is due to the uncertainty of the diagnostic criteria as previous studies showed that the prevalence of POSA differs significantly according to the definition used for the diagnosis.[14] Furthermore, it was demonstrated that the Asian population has a higher prevalence of POSA in comparison to the Western countries.[3] The prevalence of POSA among the Asian population ranged between 67% and 75% in the literature.[11,16,17] The low prevalence reported by our study can be explained by the fact that we used the overall/NS-AHI criteria for diagnosing POSA, which was shown to have the most consistent diagnostic measurements.[7] Moreover, a study conducted in the United Arab Emirates which is a part of the Mediterranean region reported a prevalence of 39.9%, using the supine AHI/nonsupine AHI ≥2 definition, which is similar to the prevalence reported in our study.[18]

Our results showed a significant difference between POSA and NPOSA patients in the sex distribution, BMI, hypertension, and HbA1c levels. Females had significantly higher prevalence of POSA, which is consistent with several studies that also showed that females are more affected with POSA.[18,19] The difference in the prevalence of POSA between males and females might be due to hormonal effects as females tend to have gynecoid deposition of fat, whereas males typically have truncal obesity which overcomes the positional effect and generates OSA in all positions.[20] Furthermore, BMI was significantly lower among the POSA patients when compared to NPOSA patients, which is also consistent with previous studies.[18,21] The lower BMI observed among POSA patients suggested that POSA might represent an early stage of OSA that will become NPOSA with increasing BMI. This evidence might be supported by the studies that showed that reduction in weight after bariatric surgery was associated with an increase in the prevalence of POSA at the expense of NPOSA.[22] Similar to previous studies, our study showed that POSA patients had lower prevalence of hypertension.[18] It was demonstrated that OSA patients have higher blood pressure readings due to the sympathetic hyperactivity in those patients.[3] Since patients with POSA have lower OSA severity than NPOSA patients, it is expected to observe lower sympathetic activity among those patients and hence lower BP reading and prevalence of hypertension.[3] In addition, we found that HbA1c levels were significantly lower among POSA patients than NPOSA. This might be due to the low BMI among POSA patients in comparison to NPOSA patients, which results in lower insulin resistance and lower HbA1c levels.[23] However, the prevalence of diabetes mellitus was not significantly different between POSA and NPOSA patients, which contradicts previous studies.[24] Moreover, we did not find any difference between POSA and NPOSA patients in the prevalence of heart failure, thyroid diseases, Vitamin D deficiency, anemia, or thyroid hormone status. Furthermore, the mean levels of creatinine, Vitamin D, ESR, CRP, ferritin, WBC, TSH, and thyroxine were not significantly different between POSA and NPOSA patients. Finally, the multivariate regression analysis model showed that only female gender and hypertension were significantly associated with POSA after adjusting for confounding variables.

Regarding polysomnographic characteristics, AHI and severe OSA were significantly higher among NPOSA patients than POSA patients. Both findings are consistent with previous studies and indicate that POSA patients have milder OSA than NPOSA patients.[16] Furthermore, REM-AHI, NREM-AHI, supine AHI, nonsupine AHI, and left and right AHI were also significantly higher among NPOSA patients than POSA patients, which is similar to the findings of previous studies which also suggest more severe disease among NPOSA patients regardless of the position during sleep.[16,25] Thus, it is important to differentiate between POSA and NPOSA patients as NPOSA patients have a high AHI in all positions and hence would not respond to PT. Moreover, similar to previous studies, sleep efficiency was significantly higher among POSA patients indicating better sleeping quality among those patients.[16] In addition, we found that total sleeping time was significantly higher among POSA patients, indicating that they also have better sleeping quantity. Furthermore, supine sleep time was significantly higher among POSA patients, while nonsupine time was higher among NPOSA ones. Oxygen saturation findings in our study showed that POSA patients had significantly higher SpO_2 in awake, REM, and NREM as well as higher SpO_2 nadir, which is consistent with previous studies.[26] Furthermore, the time of SpO_2 readings below 90% was significantly lower among POSA patients. The apnea and hypoxia severity findings might be explained by several hypotheses including the pharyngeal airway collapsibility hypothesis. It was hypothesized that the mechanism behind OSA is characterized by decreased or complete loss of tone of the genioglossus muscle resulting in pharyngeal collapse and apnea events during sleep.[27,28] NPOSA patients might have higher airway collapsibility, which results in more apneic events in all sleep positions compared to POSA patients who experience them mainly during the supine position. The supine position by the effect of gravity adds to the forces of airway collapse in POSA patients which result in apnea mainly in the supine position.[29,30] Furthermore, the gravity force will exert its effect on NPOSA patients, who have more susceptible airways, resulting in more severe apnea in the supine position. Similarly, our results showed that NPOSA patients have higher AHI events in all positions including the supine position. This indicates that NPOSA patients had higher tendency of airway collapse and would be affected by apneic events regardless of the body position. Moreover, it was also demonstrated that in those patients during wakefulness, pharyngeal patency is maintained preventing any apnea events,[31] yet we found that NPOSA patients have also lower SpO_2 during wakefulness, indicating that NPOSA patients might have a higher pharyngeal collapsibility even in the wakefulness. It is important to mention that we did not investigate the differences in pharyngeal airway collapse differences between POSA and NPOSA patients. Thus, future studies are recommended to study the differences in pharyngeal airway collapse between POSA and NPOSA patients.

This study has several limitations. First, the single-center design limits the generalizability of our results. Second, the retrospective design limits our inferences between the included variables to association and not causation. Hence, future large well-conducted multicenter studies are recommended to study the differences between POSA and NPOSA patients. Furthermore, despite the fact that we used the most consistent definition and the one that identifies patients with higher probability to benefit from PT according to the literature, several definitions were proposed to identify POSA patients. Finally, the diagnosis of POSA was made based on single night PSG and it is unknown if POSA is a stable night to night phenotype or not.

To conclude, the prevalence of POSA in our study was 41.7%. A higher prevalence of female sex, a lower hypertension prevalence, a lower BMI, and HbA1c levels were demonstrated among POSA compared to NPOSA patients. However, the multivariate regression analysis showed that only female gender and hypertension were significantly associated with POSA. Furthermore, the prevalence of severe OSA as well as AHI in all positions was significantly higher among NPOSA patients. Furthermore, oxygen saturation measures were significantly lower among NPOSA patients, whereas sleep efficiency and total sleep time were significantly higher in POSA patients. Considering the high prevalence of POSA among OSA patients, future prospective studies are needed to further confirm our findings regarding the airway collapse hypothesis, better characterize the POSA patients, and investigate the benefit of PT on those patients.

Contributions

KA and AAT were involved in conceptualization; KA, ASA, AAT, EA, MMH, AAA, and RAS were involved in data curation, formal analysis, investigation, methodology, project administration, resources, software, validation, visualization, and writing the original draft; and KA and AAT were involved in supervision and reviewing and editing the manuscript.

Data sharing

The data associated with this manuscript are available from the corresponding author upon reasonable request.

Ethical approval

This study was approved by the Institutional Review Board (IRB) of the JUH (IRB#1020222444) and the IRB waived the need for consent from the participants. This

study was conducted in accordance with the Declaration of Helsinki.

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Conflicts of interest
There are no conflicts of interest.

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