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Original Article

Prevalence and characteristics of positional sleep apnea in the HypnoLaus population-based cohort

Raphael Heinzer [a, *, 1], Nicolas J. Petitpierre [a, 1], Helena Marti-Soler [b], José Haba-Rubio [a]

[a] Center for Investigation and Research in Sleep, University Hospital of Lausanne (CHUV), Rue du Bugnon 46, 1011, Lausanne, Switzerland
[b] Institute of Social and Preventive Medicine, University of Lausanne, Route de la Corniche 10, 1010, Lausanne, Switzerland

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ABSTRACT

Objective/Background: To determine the prevalence of positional obstructive sleep apnea (POSA) and exclusive POSA (ePOSA) in the general population and to assess the factors independently associated with POSA and ePOSA according to gender and menopausal status.
Patients/Methods: Participants of the population-based HypnoLaus Sleep Cohort underwent full polysomnography at home. POSA was defined as an apnea-hypopnea index (AHI) ≥5/h, and supine/non-supine AHI ratio (sAHI/nsAHI) ≥2 (ePOSA when non-supine AHI was normalized).
Results: In this study, 1719 subjects (40-85y.o. 46% men) with at least 30 min spent in both the supine and non-supine positions were included. OSA was present in 1224 subjects (71%) (AHI >5/H). POSA was present in 53% of all subjects, and in 75% of OSA subjects. ePOSA was present in 26% of all subjects and in 36% of OSA subjects. In multivariate analyses, lower AHI and lower BMI were both associated with POSA and ePOSA in males. In premenopausal females, no single factor was associated with POSA while a lower AHI and an Epworth sleepiness scale >10 were associated with ePOSA. In postmenopausal women, a lower BMI was associated with POSA and a lower AHI and a lower Mallampati score with ePOSA.
Conclusions: In this large population-based study, we found that POSA is present in 53% of the middle-to-older age general population, and in 75% of OSA subjects. ePOSA was present in 36% of OSA subjects, suggesting that a large proportion of them could be treated with positional therapy. AHI and BMI were differently associated with POSA in men, and pre or post-menopausal women.

1. Introduction

Obstructive sleep apnea (OSA) is a common condition affecting up to 49% of middle-aged men and 23% of middle-aged women [1] characterized by repetitive complete (apnea) or partial (hypopnea) collapse of the upper airway (UA) during sleep leading to sleep fragmentation, intermittent nocturnal hypoxia and activation of the sympathetic nervous system. The consequences of OSA include excessive daytime sleepiness, an increased risk of road accidents [2,3], stroke, and cardiovascular morbidity [4].

The pathophysiology of OSA is complex, with both anatomical and non-anatomical factors playing different roles and explaining the different OSA phenotypes [5]. Some patients exhibit an increased rate of respiratory events during sleep specifically in the supine position, a condition termed “supine predominant” or “positional obstructive sleep apnea” (POSA).

The definition of POSA was initially proposed by RD Cartwright in 1984 as a supine apnea/hypopnea index (sAHI) at least two times greater than the non-supine AHI (nsAHI) [6]. She also recognized that some patients had *POSA exclusive* (ePOSA), ie, they normalized their AHI in non-supine positions.

The prevalence of POSA is still debated. Oksenberg et al., [7] and Richard et al., [8] estimated that it represented approximately 60% of OSA patients, using Cartwright's criteria. Further studies based on retrospective analyses of clinical populations from Asia found prevalences ranging from 67 to 75% [9–11] and the most recent study reported a prevalence of 64–69% using slightly different diagnostic criteria [12]. Mador investigated the prevalence of ePOSA [13] and found that 27% of OSA patients fulfilled the ePOSA

Abbreviations: AHI, Apnea/Hypopnea Index; ESS, Epworth Sleepiness Scale; ePOSA, Exclusive Positional Obstructive Sleep Apnea; MAD, mandibular advancement devices; OSA, Obstructive Sleep Apnea; PT, Positional Therapy; POSA, Positional Obstructive Sleep Apnea; UA, Upper Airway; WHR, waist to hip ratio.

* Corresponding author. Center for Investigation and Research in Sleep, Lausanne University Hospital (CHUV), Rue du Bugnon 46, 1011, Lausanne, Switzerland. Fax: +41 0 21 314 6752.
E-mail address: raphael.heinzer@chuv.ch (R. Heinzer).
[1] Joint first authors.

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criteria, with a prevalence decreasing with OSA severity (49.5% of mild OSA and 6.5% of severe OSA).

Many of these studies were based on retrospective analyses of selected clinical populations using mainly thermistor sensors to assess airflow whereas nasal pressure sensors are currently used in most sleep studies. The scoring rules for respiratory events have also evolved over the years, which may have a significant impact on the AHI and its positional aspect [14–16].

The objective of this study was therefore to determine the prevalence of POSA and ePOSA in a large general population sample, using current recording techniques and scoring criteria. The secondary objective was to assess the factors independently associated with POSA and ePOSA in men and pre- and post-menopausal women.

2. Material and methods

2.1. Participants

All participants of the HypnoLaus Sleep Cohort study, previously described [1], were included in this analysis. Briefly, the HypnoLaus study included a random subset of the CoLaus/PsyCoLaus study, a population-based study from Lausanne, Switzerland, which aim was to investigate the prevalence of cardiovascular risk factors and psychiatric disorders in the general population and to identify genetic determinants and mechanisms involved in their association [17,18]. The distribution of age groups, gender, and zip codes of participants were similar to the source population [18]. The HypnoLaus participants were similar in terms of age, gender, body mass index and ethnicity (93·3% Caucasians) to the whole CoLaus/Psycolaus cohort. Menopausal status was self-reported.

2.2. Polysomnography and POSA definition

All HypnoLaus participants underwent full polysomnography (PSG) at home using Titanium recorders (Embla Flaga, Reykjavik, Iceland), which record electroencephalogram, electrooculogram, submental and leg electromyography, rib cage and abdominal movements, body position, airflow (using nasal pressure sensors) and pulse oxymetry according to the AASM 2007 recommendations [19]. Body position during the PSG recordings was determined using the Titanium built-in three dimensional accelerometer (XYZ) with a sampling rate of 32 Hz. This sensor provided the following position outputs: supine, right, left, prone or upright. We asked individuals who were currently receiving treatment for sleep-disordered breathing (n = 38) to discontinue their treatment one week before the sleep recording.

Two trained sleep technicians scored polysomnographic recordings manually using Somnologica software (version 5.1.1, Embla Flaga, Reykjavik, Iceland). Sleep stages and arousals were scored according to the 2007 AASM recommendations. Respiratory events were scored using the latest 2012 AASM criteria: apnea was defined as a drop of at least 90% of airflow from baseline, lasting 10 s or longer. Hypopnea was defined as a ≥30% drop of airflow lasting at least 10 s, associated with either an arousal or a ≥3% O_2 saturation drop [20]. The average number of apneas and hypopneas per hour of sleep (apnea-hypopnea index [AHI]) was calculated. An expert sleep clinician reviewed every recording and a second sleep expert did random quality checks. Quality control for concordance between the two polysomnography scorers was implemented periodically to ensure that both technicians achieved at least 90% agreement for sleep stages and respiratory events and an 85% level of agreement for arousals.

POSA was defined as an AHI ≥5/h, and supine/non-supine AHI ratio (sAHI/nsAHI) ≥2. Three different types of POSA exclusive (ePOSA) were also defined according to different normality thresholds for non-supine AHI (nsAHI): POSA criteria AND nsAHI <5/h (ePOSA-5), nsAHI <10/h (ePOSA-10), and nsAHI <15/h (ePOSA-15). Subjects with less than 4 h of total sleep time, and those who spent less than 30 min in the supine or non-supine positions were excluded from the analysis.

The HypnoLaus study was approved by the ethics committee of the University of Lausanne and each participant gave written informed consent.

2.3. Statistical analysis

All statistical analyses were made with Stata version 14 (College Station, TX, USA) and R (R Foundation for Statistical Computing, Vienna, Austria). We summarized data as either the number of participants (%), mean (±SD), or median [IQR]. We used bivariate analyses with the $\chi 2$ test, Student's t test, or Wilcoxon's rank-sum test where appropriate.

We also used logistic regression models to assess the association between various demographic and clinical variables and the presence of POSA and ePOSA in men, premenopausal women and postmenopausal women.

3. Results

Among the 2168 PSG recordings, 2121 were of sufficient technical quality and had at least four hours of total sleep time (TST). Of these, 1719 had at least 30 min spent in both the supine and non-supine position and were included in the analysis.

1224 subjects (71.2%) had OSA as defined by an AHI ≥5/hour. POSA was present in 914 subjects, ie in 53% of all subjects and in 75% of OSA subjects. ePOSA-5 was present in 463 (26% of all subjects and 36% of OSA subjects). ePOSA-10 was present in 396 (23% of all subjects and 47% of OSA subjects). ePOSA-15 was present in 294 (17.1% of all subjects and 49% of OSA subjects). The prevalence of ePOSA among OSA subjects according to gender and different AHI tresholds is shown in Fig. 1. Among ePOSA-5 subjects, 56 (12.7%) reported excessive daytime sleepiness (defined as an Epworth Sleepiness Scale (ESS) of more than 10 points). ePOSA-5 associated with excessive daytime sleepiness was present in 3.3% of the whole population and in 4.6% of the OSA population.

The characteristics of subjects with POSA, ePOSA and non positional OSA are shown in Tables 1a–1d. Compared to non positional OSA, subjects with POSA had a lower BMI and a lower neck circumference. Males with POSA were also slightly younger and had lower AHI.

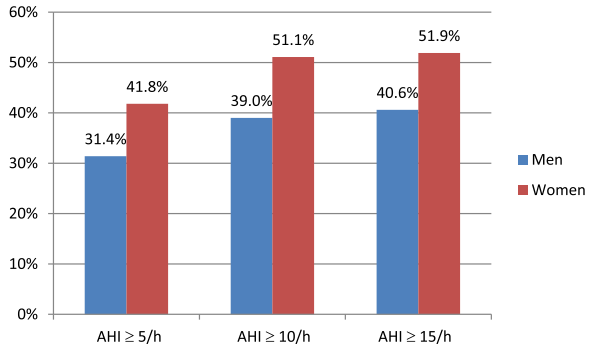

Fig. 1. Prevalence of ePOSA among OSA patients in men and women according to different "reference" AHI thresholds.

Table 1a
Characteristics of subjects with non-positional OSA (np-OSA), POSA, non-exclusive POSA (non-ePOSA) and exclusive POSA (ePOSA) among all subjects with an AHI ≥5/h.

	np-OSA	POSA	P	non-ePOSA	ePOSA	P
N (%)	310 (25)	914 (75)		783 (64)	441 (36)	
Age (yr)	61.0 (11.2)	59.3 (10.8)	0.020	60.6 (10.8)	58.1 (11.0)	<0.001
BMI (kg/m^2)	28.0 (4.8)	26.5 (3.9)	<0.001	27.6 (4.4)	25.5 (3.5)	<0.001
WHR	0.93 (0.07)	0.93 (0.07)	0.030	0.94 (0.07)	0.91 (0.07)	<0.001
Neck circ (cm)	38.1 (3.8)	37.3 (3.7)	<0.001	38.1 (3.7)	36.3 (3.5)	<0.001
Mallampati	2.7 (1.0)	2.6 (0.9)	0.165	2.8 (0.9)	2.5 (1.0)	<0.001
Epworth score	6.3 (3.6)	6.2 (3.8)	0.756	6.3 (3.7)	6.1 (3.9)	0.438
AHI	18.2 [9.6–35.0]	13.9 [9.0–23.0]	<0.001	20.1 [12.2–33.2]	9.2 [6.9–13.9]	<0.001

Data are number of participants (%), mean (SD) or median [IQR]. BMI: body-mass index, WHR: Waist-to-hip ratio, AHI: apnea-hypopnea index, REM: Rapid Eye Movement sleep.

Table 1b
Characteristics of subjects with non-positional OSA, POSA, non ePOSA and ePOSA among MEN with an AHI ≥5/h.

	np-OSA	POSA	P	non-ePOSA	ePOSA	P
N (%)	179 (26)	499 (74)		465 (69)	213 (31)	
Age (yr)	59.8 (11.2)	57.2 (10.7)	0.006	59.2 (10.9)	54.9 (10.5)	<0.001
BMI (kg/m^2)	27.9 (4.4)	26.6 (3.4)	<0.001	27.5 (3.9)	25.8 (3.2)	<0.001
WHR	0.935 (0.065)	0.925 (0.067)	0.030	0.936 (0.065)	0.912 (0.066)	<0.001
Neck circ (cm)	40.3 (3.0)	39.7 (2.6)	0.013	40.2 (2.8)	39.1 (2.5)	<0.001
Mallampati	2.8 (1.0)	2.8 (0.9)	0.837	2.9 (0.9)	2.7 (1.0)	0.039
Epworth score	6.6 (3.9)	6.7 (3.9)	0.597	6.7 (3.9)	6.8 (3.9)	0.647
AHI	23.0 [12.7–45.0]	16.1 [10.0–26.6]	<0.001	20.1 [12.2–33.2]	9.2 [6.9–13.9]	<0.001

Data are number of participants (%), mean (SD) or median [IQR]. BMI: body-mass index, WHR: Waist-to-hip ratio, AHI: apnea-hypopnea index, REM: Rapid Eye Movement sleep.

Table 1c
Characteristics of subjects with non-positional OSA, POSA, non-ePOSA and ePOSA among premenopausal women with an AHI ≥5/h.

	np-OSA	POSA	P	non-ePOSA	ePOSA	P
N (%)	21 (23)	69 (77)		47 (52)	43 (48)	
Age (yr)	47.2 (3.4)	48.0 (4.6)	0.447	47.9 (4.7)	47.7 (4.1)	0.850
BMI (kg/m^2)	28.0 (4.6)	26.8 (5.0)	0.313	27.5 (5.0)	26.6 (4.8)	0.387
WHR	0.886 (0.051)	0.878 (0.053)	0.547	0.887 (0.046)	0.872 (0.058)	0.176
Neck circ (cm)	35.5 (2.6)	34.4 (2.5)	0.103	35.2 (2.7)	34.3 (2.5)	0.113
Mallampati	2.5 (1.1)	2.5 (1.0)	0.859	2.6 (1.0)	2.4 (1.0)	0.470
Epworth score	7.5 (3.2)	7.5 (3.8)	0.979	7.3 (3.7)	7.7 (3.5)	0.631
AHI	9.8 [6.8–13.9]	9.2 [7.3–14.1]	0.928	12.2 [7.8–16.0]	8.3 [5.9–11.0]	0.001

Data are number of participants (%), mean (SD) or median [IQR]. BMI: body-mass index, WHR: Waist-to-hip ratio, AHI: apnea-hypopnea index, REM: Rapid Eye Movement sleep.

Table 1d
Characteristics of subjects with non-positional OSA, POSA, non ePOSA and ePOSA among postmenopausal women with an AHI ≥5/h.

	np-OSA	POSA	P	non-ePOSA	ePOSA	P
N (%)	108 (24)	339 (76)		264 (59)	228 (42)	
Age (yr)	65.7 (9.5)	61.9 (8.8)	0.254	65.5 (8.9)	61.1 (10.6)	0.180
BMI (kg/m^2)	28.2 (5.5)	26.1 (4.3)	<0.001	27.8 (5.2)	25.2 (3.6)	<0.001
WHR	0.904 (0.059)	0.888 (0.058)	0.017	0.899 (0.059)	0.882 (0.057)	0.002
Neck circ (cm)	35.1 (2.6)	34.3 (2.3)	0.005	35.1 (2.6)	33.8 (2.0)	<0.001
Mallampati	2.6 (1.0)	2.5 (0.9)	0.1114	2.6 (0.9)	2.3 (0.9)	<0.001
Epworth score	5.6 (3.2)	5.2 (3.5)	0.286	5.5 (3.2)	5.5 (3.9)	0.150
AHI	13.8 [9.1–26.1]	12.4 [7.9–20.4]	0.057	17.2 [10.7–26.5]	8.5 [6.5–12.9]	<0.001

Data are number of participants (%), mean (SD) or median [IQR]. BMI: body-mass index, WHR: Waist-to-hip ratio, AHI: apnea-hypopnea index, REM: Rapid Eye Movement sleep.

Compared to non-positional OSA and POSA, subjects with ePOSA-5 showed the same differences and also had a lower waist to hip ratio (WHR) and a lower Mallampati score. The mean ESS score was not different between groups.

In the whole population, there were statistically significant differences between pre-, post-menopausal women and men in terms of BMI, WHR and neck circumference, with men having the highest and premenauposal women the lowest values.

In the POSA population, BMI was not different between groups. WHR and neck circumferences were statistically higher in men, but there was no difference between pre and postmenopausal women.

Results of multivariate analyses are shown in Table 2. In males, AHI and BMI were both negatively associated with POSA, while a higher WHR was associated with POSA, but not with ePOSA. In premenopausal females, no single factor was associated with POSA while a lower AHI and an ESS >10 were associated with ePOSA (neck circumference showed borderline significance). In

Table 2a
Multivariate analysis for POSA in men, premenopausal women and postmenopausal women.

POSA	Premenopausal women				Postmenopausal women				Men			
	OR	95% CI		P	OR	95% CI		P	OR	95% CI		P
AHI (log)	1.096	0.364	3.298	0.871	0.864	0.575	1.300	0.484	0.594	0.438	0.806	0.001
Age	1.036	0.902	1.190	0.613	1.005	0.978	1.034	0.711	0.988	0.971	1.007	0.210
BMI	1.087	0.918	1.287	0.333	0.895	0.832	0.964	0.003	0.903	0.842	0.969	0.005
WHR	0.983	0.872	1.109	0.784	0.981	0.939	1.026	0.400	1.052	1.013	1.092	0.009
Neckcirc	0.721	0.503	1.034	0.075	1.046	0.912	1.199	0.519	1.031	0.937	1.133	0.532
Mallampati (34 vs 12)	0.966	0.329	2.840	0.950	0.780	0.482	1.264	0.313	1.162	0.779	1.734	0.462
Epworth > 10	1.995	0.471	8.453	0.349	3.075	0.930	10.165	0.066	0.945	0.557	1.603	0.832

Table 2b
Multivariate analysis for ePOSA-5 in men, premenopausal women and postmenopausal women.

ePOSA	Premenopausal women				Postmenopausal women				Men			
	OR	95% CI		P	OR	95% CI		P	OR	95% CI		P
AHI (log)	0.224	0.069	0.728	0.013	0.127	0.076	0.213	0.000	0.157	0.106	0.232	0.000
Age	0.955	0.846	1.079	0.463	1.026	0.997	1.055	0.079	0.996	0.977	1.016	0.710
BMI	1.128	0.958	1.329	0.149	0.940	0.866	1.021	0.141	0.904	0.828	0.987	0.024
WHR	0.934	0.833	1.048	0.244	0.979	0.938	1.022	0.333	1.024	0.983	1.067	0.255
Neckcirc	0.724	0.510	1.026	0.070	0.893	0.773	1.031	0.121	1.008	0.908	1.118	0.886
Mallampati (34 vs 12)	1.467	0.518	4.157	0.470	0.601	0.371	0.973	0.038	0.913	0.599	1.392	0.673
Epworth > 10	5.407	1.320	22.148	0.019	1.563	0.603	4.051	0.358	1.239	0.709	2.165	0.452

postmenopausal women, a lower BMI was associated with POSA and a lower AHI and a lower Mallampati score with ePOSA. The stronger association between AHI and WHR in men than in women is shown in Fig. 2.

4. Discussion

The main finding of this study is that the prevalence of positional sleep apnea in this middle to older age general population is higher than expected, with 53% of our sample having POSA and 26% having ePOSA using an AHI threshold of ≥5/h. To the best of our knowledge, this is the first study reporting the prevalence of POSA and ePOSA in the general population. Our results also confirm the high proportion of positional sleep apnea among OSA subjects (POSA prevalence was 76% in women and 74% in men, and ePOSA prevalence was 42% in women and 31% in men), which corresponds to the upper range of the prevalences reported in previous studies [7–12]. Furthermore, the detailed phenotyping of our cohort's subjects allowed to precisely analyze the characteristics of POSA and ePOSA. We believe that these results are important from a clinical point of view since they not only show that POSA is highly prevalent in the middle to older age population but also that about a third of OSA patients could be efficiently treated with a positional therapy (even when considering different AHI reference thresholds [<5/h, <10/h or <15/h]).

Considering the high prevalence of OSA found in the general population with current recording techniques and scoring criteria [1,21], resource-demanding treatments such as continuous positive airway pressure (CPAP) and mandibular advancement devices (MAD) cannot be provided to all OSA patients and are usually kept for the most severe cases. For milder cases, among which POSA and ePOSA are even more prevalent, a cheaper treatment such as positional therapy (PT), allowing patients to avoid sleep in the supine position, could be considered. PT could also be used as a second line treatment for moderate or severe cases who do not tolerate first line treatments such as CPAP or MAD. Different forms of PT devices can be used, such as the “tennis ball technique” or commercial waist bands; which are either bulky or uncomfortable in the supine position can be used to prevent supine posture during sleep. These types of PT have been used for a long time however they have been

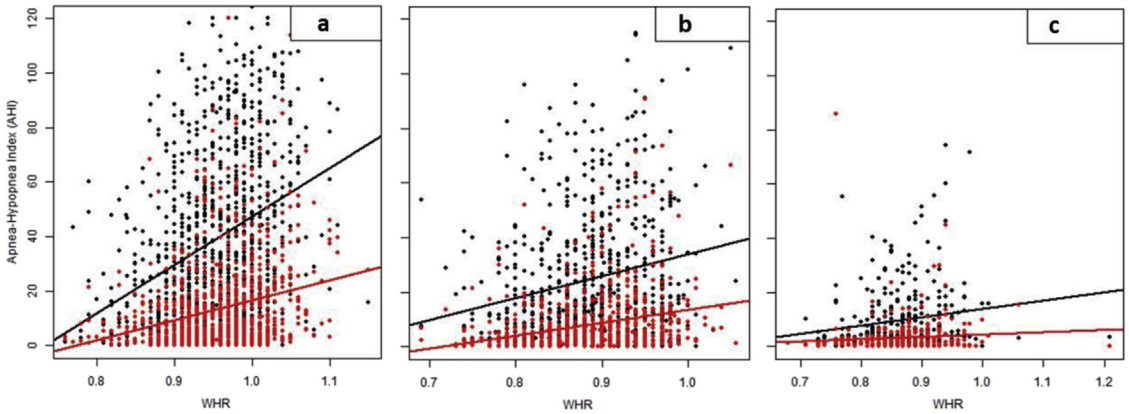

Fig. 2. Supine (black) and non-supine (red) AHI vs Waist to hip ratio (WHR) in men (a), postmenauposal women (b) and premenauposal women (c). (For interpretation of the references to color/colour in this figure legend, the reader is referred to the Web version of this article.)

shown to be effective, as patients' adherence appears to be satisfactory only in the short term [22]. Furthermore, adherence seems to worsen over time with nearly two thirds of patients discontinuing treatment after one year and over 80% after two years [23,24]. More recently, active positional therapy using small neck- or chest-worn devices which vibrate in the supine position was developed [25,26]. These types of devices seem to be better tolerated [27] and are able to provide objective feedback on usage time and on the proportion of the night spent in the supine position to the patients and their physicians [28,29]. Dieltjens et al. also suggested that PT could be used together with MAD and with a possible synergic effect since both therapies tend to stabilize passive airway anatomy/collapsibility [30–32].

A number of factors have been shown to be associated with the presence of POSA and ePOSA in previous studies. These include milder OSA (lower AHI), lower BMI, and younger age [7,11–13]. In the present study, we also found that these factors were associated with POSA in bivariate analysis. This suggests that POSA could represent an early stage of the sleep disordered breathing continuum that may develop in non positional OSA with increasing age and weight. Although this has not been formally demonstrated in a prospective study, weight reduction through bariatric surgery is associated with an increased proportion of POSA [33].

The results of the multivariate analysis show that factors associated with POSA and ePOSA differ between genders and also by hormonal status. The negative association between AHI severity and ePOSA is easily explained by the definition of ePOSA: with severe OSA, even an important decrease in respiratory events in the non supine position might be insufficient to reach a sAHI lower than 5, 10, or 15/h. The presence of an independent association between POSA and lower BMI in men and post menopausal women could be due to a gender and hormone specific patterns of fat deposition: premenopausal women tend to have a gynoid fat distribution in the lower part of the body while men and postmenopausal women tend to have a more truncular obesity [34] that may overcome the positional effect and generate OSA in any position when BMI increases. Notably, a higher waist to hip ratio (WHR) was associated with POSA in men. This suggests that abdominal obesity in men may induce POSA by causing a rostral displacement of the diaphragmatic domes in the supine position, which in turn diminishes the axial tension exerted on the pharyngeal walls through the mediastinum, thus increasing the pharyngeal compliance and favoring its collapse [35–37]. In support of this hypothesis, a recent study showed that POSA patients, as compared to controls and REM dominant OSA, show a decrease in functional residual capacity when moving from lateral to supine position [38].

The absence of any significant factor associated with POSA in premenopausal women in our study could be explained by a lack of statistical power (there were only 90 premenauposal OSA subjects in the cohort). Alternatively, this may be explained by the fact that POSA is not a stable phenotype in women, as suggested in a recent study [39], or that other factors not considered in our study such as respiratory control instability (high loop gain) could be involved.

The main strength of our study is the inclusion of a large, population-based sample including unselected subjects instead of patients referred for suspected OSA as in previous studies. Moreover, all subjects had complete PSG recordings with current recording techniques (nasal pressure) and up to date scoring criteria (AASM 2012). Finally, the extensive phenotyping of the cohort allowed us to perform multivariate analysis using all relevant demographic parameters including menopausal status.

Our study has also some limitations that need to be acknowledged. First, different definitions of POSA have been proposed in the literature according to different non supine/supine AHI ratio thresholds, taking into account or not the time spent in different positions [6,13,39–41]. We decided to use the two most commonly used definitions (Cartwright POSA and ePOSA definitions) and to add a minimum of 30 min of sleep spent in the supine and non supine positions to avoid extreme AHI due to low denominator. Although the clinical and therapeutic implications of these definitions are still unclear, we believe that ePOSA is the entity most likely to identify patients likely to respond to positional treatment, as previously suggested by other authors [13,42]. Second, the diagnosis of POSA was made on a single night PSG recording. As discussed above, it is currently unknown if POSA is a stable night to night phenotype or not, especially in women [39]. Finally, we could not correct the position signal of the recorder using video recordings since the sleep studies were performed in the subjects' home environment. This may have yielded some inaccuracies in the evaulation of the actual posture of the participants.

Conclusion

In this large middle to older age population-based sample, we found that POSA was present in 53% of all subjects, and in 75% of subjects with an AHI $\geq$5/h. ePOSA was present in 36% of OSA subjects, suggesting that a large proportion of them could be treated with positional therapy. Although POSA, which is associated with lower AHI and BMI, seems to represent an early stage of the OSA continuum, we found that these factors were differently associated with POSA in men, and pre or post-menopausal women in multivariate analyses, probably due to gender and hormonal associated fat distribution patterns. Further prospective studies are needed to determine the best definition of POSA, and to identify clinical characteristics that will predict a good response to positional therapy.

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Disclosure statement

RH is member of the medical advisory board of Nightbalance company.

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Conflicts of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2018.02.011.

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