Prevalence, treatment and determinants of obstructive sleep apnoea and its symptoms in a population-based French cohort

Pauline Balagny[1,2,3], Emmanuelle Vidal-Petiot[1,2,4], Adeline Renuy[3], Joane Matta[3], Justine Frija-Masson[1,2,5], Philippe Gabriel Steg[1,4,6,7], Marcel Goldberg[3], Marie Zins[1,3], Marie-Pia d'Ortho[1,2,5] and Emmanuel Wiernik[3]

[1]Université Paris Cité, UFR de Médecine, Paris, France. [2]Service de Physiologie Explorations Fonctionnelles, AP-HP, Hôpital Bichat, Paris, France. [3]Université Paris Cité, Population-based Cohorts Unit, INSERM, Paris Saclay University, Université de Versailles Saint-Quentin-en-Yvelines, UMS 011, Paris, France. [4]INSERM U1148, Laboratory for Vascular Translational Science, Paris, France. [5]INSERM U1141, NeuroDiderot, Paris, France. [6]Département de Cardiologie, AP-HP, Hôpital Bichat, Paris, France. [7]Institut Universitaire de France, Paris, France.

Corresponding author: Pauline Balagny (pauline.balagny@aphp.fr)

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In the French population, treated sleep apnoea prevalence is 3.5%, but 18.1% of untreated patients have a positive BQ; age, obesity, depression, unhealthy behaviours and socioeconomic conditions are associated with treated sleep apnoea or high risk of OSA https://bit.ly/40qimwU

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Abstract

Background Obstructive sleep apnoea (OSA) is associated with increased morbidity and mortality. Although the disorder has been well studied in selected high-risk populations, few data exist on its prevalence in the general population. We aimed to assess the prevalence and determinants of OSA in France.

Methods Data from participants of the French population-based CONSTANCES cohort aged 18–69 years at inclusion and being treated for sleep apnoea or screened for OSA in 2017 using the Berlin Questionnaire were analysed. Weighted analyses were performed to provide recent and representative results in the general population.

Results Among 20 151 participants, the prevalence of treated sleep apnoea was 3.5% (95% CI 3.0–3.9%). The prevalence of untreated subjects with a positive Berlin Questionnaire was 18.1% (95% CI 17.3–19.2%) for a total weighted prevalence of treated sleep apnoea or high risk of OSA of 20.9% (95% CI 20.0–21.9%). Regarding prevalence of OSA symptoms, it was 37.2% (95% CI 36.1–38.3%) for severe snoring and 14.6% (95% CI 13.8–15.5%) for hypersomnolence. In multivariable logistic regression analysis, male sex, age, previous cardiovascular events, smoking, low educational level, low physical activity and depressive symptoms were associated with having either treated sleep apnoea or a positive Berlin Questionnaire.

Conclusion In this large French population-based cohort, one in five participants had a high likelihood of OSA, whereas only 3.5% were treated for the disorder, suggesting major underdiagnosis in the general population. OSA diagnosis should be considered more often in people with risk factors such as depressive symptoms as well as unhealthy behaviours and socioeconomic conditions.

Introduction

Obstructive sleep apnoea (OSA) syndrome is defined by the association of symptoms (*e.g.* sleepiness, fatigue, insomnia, snoring, subjective nocturnal respiratory disturbance or observed apnoea) or disorders (*i.e.* hypertension, heart diseases, stroke, diabetes, cognitive dysfunction or mood disorder) with an apnoea–hypopnoea index (AHI) $\geqslant$5 events·h^{-1}. Alternatively, an AHI $\geqslant$15 events·h^{-1} defines OSA even in the absence of associated symptoms or disorders [1]. Untreated OSA is associated with increased risks of cardiovascular disease and neurocognitive sequelae. OSA is a frequent syndrome, although its reported prevalence varies greatly according to the population and diagnostic procedure [2]. In a seminal study

conducted in the early 1990s, using an AHI cut-off of 5 events·h^{-1} combined with symptoms, sleep apnoea syndrome was reported to affect 4% of males and 2% of females in the general population [3]. In more recent population-based studies, the prevalence of OSA was estimated to be higher, from 14% to 50% in men and from 5% to 23% in women [4, 5], likely reflecting the obesity epidemic.

Determining the prevalence of OSA and characteristics of individuals at high risk of OSA will help improve targeted and efficient prevention and screening strategies. In France, the prevalence of treated OSA is estimated to be 2.4% [6, 7]. However, OSA is largely underdiagnosed and undertreated [8, 9], and the real prevalence of the disorder is thought to be higher [10, 11]. Male sex, age and obesity are well-known determinants of OSA, but the role of other behavioural and socioeconomic factors remains unclear [3, 5, 6, 10, 12–18].

Polysomnography is the gold standard diagnostic procedure [19], but has limited availability. Alternatively, screening questionnaires such as the Berlin Questionnaire have been developed. The Berlin Questionnaire relies on the presence of heavy snoring and hypersomnolence (the most frequent symptoms of sleep apnoea [6, 10, 11, 18, 20, 21]), on obesity (a major causal factor of the disorder), and on hypertension (a consequence of intermittent hypoxia). This questionnaire has been validated to diagnose AHI $\geqslant$5 events·h^{-1} with a sensitivity of 76–95% [22–26].

The aim of the study was to assess the prevalence and determinants of OSA assessed as treated sleep apnoea and through the Berlin Questionnaire in the French population-based CONSTANCES cohort. Weighted analyses were performed to provide representative results in the general population.

Methods

Study design and participants

The CONSTANCES cohort included more than 200 000 volunteers aged 18–69 years from 21 departments throughout metropolitan France recruited between 2012 and 2020 [27]. Eligible individuals were selected from the adult population covered by the general insurance scheme (representing 85% of the French population) using a random sampling scheme stratified on place of residence, age, sex, occupation and socioeconomic status in order to be representative of the source population. At inclusion, participants underwent a clinical interview, examination, standard biology testing and completed questionnaires including sociodemographic characteristics. Follow-up was performed through yearly self-administered questionnaires.

The present analyses were restricted to individuals invited to participate in 2013 and 2014 who had completed the 2017 follow-up questionnaire, which included items of the Berlin Questionnaire. This allowed the use of weighting coefficients (see Weighting coefficients section) to provide a representative sample of the general French population aged 18–69 years covered by the general insurance scheme in the selected departments of CONSTANCES (figure 1).

The CONSTANCES cohort obtained the authorisation of the National Data Protection Authority (Commission Nationale de l'Informatique et des Libertés; 910486) and was approved by the Institutional Review Board of the National Institute for Medical Research (INSERM; 01-011). Written informed consent was received from all participants.

OSA evaluation

Two situations were considered: either a confirmed prior diagnosis of sleep apnoea with ongoing treatment, as self-reported by respondents in the 2017 CONSTANCES questionnaire, or being at high risk of OSA based on the Berlin Questionnaire. This self-administered questionnaire consists of 10 questions covering three categories: 1) snoring and its loudness, frequency and inconvenience to others, as well as witnessed apnoeas; 2) hypersomnolence and its severity; and 3) history of arterial hypertension or obesity, as defined by body mass index (BMI) $\geqslant$30 kg·m^{-2}. Two or more positive categories defined a high risk for OSA [22]. History of arterial hypertension was either physician-reported at the inclusion visit or self-reported in the yearly questionnaires until 2017. BMI was calculated from the most recent available weight until 2017 (either self-reported in the yearly follow-up questionnaire or measured at the inclusion visit) and from height measured at the inclusion visit.

Weighting coefficients

A weighting coefficient was computed for each subject when data were available. This coefficient took into account both the survey weight and the non-participation correction factor, based on the follow-up of a control cohort of non-participants [28, 29]. In cases where the medico-administrative data of a participant

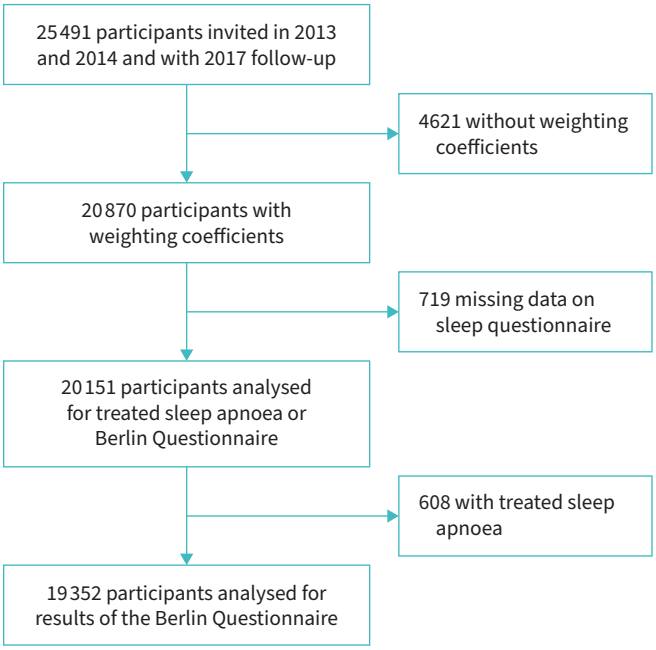

FIGURE 1 Flow diagram of the study population.

could not be obtained, the weighting coefficient could not be calculated. However, participants with or without a weight had the same characteristics. Moreover, the probability of having completed the 2017 follow-up questionnaire was estimated for each participant in order to compute a participation weight for this follow-up. The product of this weight with the weight at baseline provided the final weight.

Statistical analyses

Categorical variables were described as numbers and percentages with their 95% confidence intervals in the entire study population, and then according to the presence of sleep apnoea, snoring or hypersomnolence. Groups were compared using Chi-squared tests.

We used logistic regressions to compute risks of sleep apnoea, snoring and hypersomnolence. Multiple imputations by chained equations (10 imputations with 100 iterations) were performed to handle missing data for variables of the model.

All analyses were performed using Stata version 15.1 (StataCorp, College Station, TX, USA).

Covariates

According to a directed acyclic graph, the following covariates (defined as detailed in table 1) were retained: sex, age in 2017, marital status at baseline, monthly household income at baseline and educational level at baseline. Smoking status and alcohol consumption were defined by the last self-reported value in the inclusion or follow-up questionnaire until 2017. Self-reported physical activity at baseline was based on the following questions: 1) "In the past 12 months have you regularly engaged in gardening, cleaning or handy work?", 2) "In the past 12 months have you regularly practiced sport (aside from gardening, cleaning or handy work)?" and 3) "In the past 12 months have you regularly gone on biking or walking trips (for work or leisure)?". Depressive symptoms were collected at baseline using the Center of Epidemiologic Studies Depressive Scale (CES-D). A global score $\geqslant$19 was used to provide a proxy of depressive state [30]. History of myocardial infarction or stroke was physician-reported at the inclusion visit or self-reported in the follow-up yearly questionnaires until 2017.

We did not adjust for hypertension, diabetes or dyslipidaemia, which in our directed acyclic graph were considered as a consequence and not a cause of OSA, nor for obesity because it is part of the Berlin Questionnaire.

TABLE 1 Population characteristics

	Total population (n=20 151)	Treated sleep apnoea or positive Berlin Questionnaire (n=3914)	No treated sleep apnoea and negative Berlin Questionnaire (n=16 237)	p-value
Male	9356 (47.8 (46.7–48.9))	2193 (55.0 (52.5–57.6))	7163 (45.8 (44.6–47.1))	<0.001
Age group (years)				<0.001
<40	1555 (14.9 (14.0–15.9))	368 (16.1 (14.1–18.3))	3414 (33.9 (32.6–35.2))	
40–49	4726 (23.5 (22.6–24.4))	598 (22.1 (19.9–24.5))	3644 (24.9 (23.8–26.0))	
50–59	5110 (19.4 (18.6–20.2))	1080 (24.7 (22.6–26.8))	4039 (19.6 (18.7–20.6))	
⩾60	5362 (18.8 (18.0–19.6))	1868 (37.1 (34.8–39.5))	5140 (21.6 (20.7–22.5))	
Myocardial infarction	234 (1.4 (1.2–1.8))	107 (3.2 (2.4–4.3))	127 (1.0 (0.7–1.3))	<0.001
Stroke	267 (1.3 (1.0–1.5))	109 (2.8 (2.0–3.9))	158 (0.9 (0.7–1.2))	<0.001
Household income (EUR)				<0.001
<1500	1625 (15.7 (14.8–16.7))	402 (19.8 (17.5–22.2))	1223 (14.3 (13.3–15.3))	
1500–2800	5069 (28.3 (27.3–29.3))	1070 (30.8 (28.4–33.2))	3999 (26.9 (25.8–28.0))	
>2800	12 304 (51.0 (49.8–52.1))	2230 (43.4 (41.0–45.9))	10 074 (51.7 (50.4–52.9))	
Other	860 (5.0 (4.5–5.6))	163 (4.5 (3.5–5.7))	697 (5.0 (4.5–5.7))	
Missing	293	49	244	
Educational level				<0.001
⩽High school degree	7992 (46.4 (45.2–47.5))	2001 (60.0 (57.5–62.3))	5991 (41.9 (40.6–43.1))	
Undergraduate degree	6970 (32.4 (31.4–33.4))	1199 (25.6 (23.6–27.8))	5771 (33.8 (32.4–34.7))	
Postgraduate degree	4913 (21.2 (20.4–22.1))	658 (12.4 (11.1–13.9))	4255 (23.3 (22.2–24.1))	
Missing	276	56	220	
Smoking				<0.001
Non-smoker	9193 (44.7 (43.5–45.8))	1525 (36.5 (34.0–39.0))	7668 (46.8 (45.6–48.1))	
Ex-smoker	7979 (36.2 (35.1–37.2))	1726 (40.6 (38.1–43.1))	6253 (35.0 (33.8–36.2))	
Current smoker	2388 (19.2 (18.2–20.2))	517 (23.0 (21.0–25.5))	1871 (18.2 (17.1–19.3))	
Missing	591	146	445	
Alcohol consumption				<0.001
None	3843 (22.0 (21.0–23.0))	731 (23.0 (20.8–25.4))	2975 (20.8 (19.8–21.9))	
⩽3/2 drinks per day in men/women	13 755 (64.7 (63.6–65.8))	2432 (57.2 (54.6–59.7))	10 928 (62.8 (64.8–65.3))	
>3/2 drinks per day in men/women	2773 (13.3 (12.6–14.1))	653 (15.6 (13.9–17.6))	2035 (12.2 (11.4–13.0))	
Missing	397	98	299	
Physical activity				<0.001
Few or not	5139 (29.3 (28.2–30.3))	462 (15.1 (13.2–17.2))	1239 (9.3 (8.5–10.1))	
Moderate	9021 (45.6 (28.2–30.3))	2411 (62.3 (59.8–64.8))	10 048 (64.9 (63.7–66.1))	
High	5991 (25.2 (28.2–30.3))	899 (17.9 (16.2–19.7))	4483 (23.0 (22.0–24.0))	
Missing	609	142	467	
Obesity	2259 (14.2 (13.4–15.1))	1577 (46.2 (43.6–48.8))	840 (7.3 (6.6–8.1))	<0.001
Missing	83	13	70	
Depressive symptoms	2637 (8.3 (8.3–8.3))	813 (27.8 (25.4–30.3))	1824 (13.5 (12.6–14.5))	<0.001
Missing	985	252	733	
Married/in civil partnership	12 667 (55.1 (54.0–56.3))	2580 (57.6 (55.0–60.1))	10 087 (54.5 (53.2–55.7))	<0.001
Missing	312	57	255	

Data are presented as n (% (95% CI)) or n, unless otherwise stated; percentages are weighted in order to provide results representative of the French general population aged 18–69 years in the selected departments of CONSTANCES and covered by the general insurance scheme.

When snoring and hypersomnolence were used as outcomes, the sample was restricted to participants without self-reported treated sleep apnoea, since symptoms could be modified by treatment, and an additional model was further adjusted for obesity.

Results

The flow diagram of the study population is shown in figure 1. From the 25 491 participants invited in 2013 and 2014 and who responded to the 2017 CONSTANCES questionnaire, weighted data for OSA were available in 20 151 (79.0%) participants.

Prevalence of OSA and determinants

Characteristics of study participants are shown in table 1. Treated sleep apnoea was reported by 608 participants, corresponding to a weighted prevalence of 3.5% (95% CI 3.0–3.9%), with 5.0% (95% CI

4.3–5.8%) in men and 2.0% (95% CI 1.6–2.6%) in women. Among the remaining participants, 3306 had a positive Berlin Questionnaire (18.1% (95% CI 17.3–19.2%), with 20.2% (95% CI 18.9–21.6%) in men and 16.4% (95% CI 15.3–17.7%) in women), resulting in a total weighted estimated prevalence of treated sleep apnoea or high risk of OSA of 20.9% (95% CI 20.0–21.9%) in the French population. This prevalence was higher in men (24.1% (95% CI 22.7–25.6%)) than in women (18.0% (95% CI 16.8–19.3%); p<0.001) and increased with age: 11.1% (95% CI 9.7–12.8%) in participants <40 years old, 19.1% (95% CI 17.1–21.2%) in participants 40–49 years old, 25.0% (95% CI 23.0–27.1%) in participants 50–59 years old and 31.3% (95% CI 29.5–33.2%) in participants ⩾60 years old (p-value for linear trend <0.001). Treated sleep apnoea or high risk of OSA was also more frequent in smokers, in participants with no alcohol consumption or alcohol consumption above recommended thresholds (compared with moderate consumption) and in those with a low level of physical activity. Finally, treated sleep apnoea or high risk of OSA was more frequent in people with a history of myocardial infarction and stroke, low income, low educational level, and with symptoms of depression (table 1).

Characteristics of participants with treated sleep apnoea compared with those with a positive Berlin Questionnaire are presented in supplementary table S1. Participants with treated sleep apnoea were more often men, older, with a higher rate of myocardial infarction, stroke and obesity, and lower educational and physical activity levels.

Unadjusted analyses are reported in supplementary table S2. In multivariable analyses (figure 2), treated sleep apnoea or high risk of OSA were independently associated with male sex, higher age, previous cardiovascular events, lower socioeconomic status, former or current smoking, no alcohol consumption, a lower level of physical activity, depressive symptoms and marital status. Results were similar when excluding participants with treated OSA (supplementary table S3).

Prevalence and determinants of symptoms of OSA

Detailed results of all items and categories of the Berlin Questionnaire are shown in figure 3. Prevalence of heavy snoring (positivity of category 1) was 37.2% (95% CI 36.1–38.3%). It was higher in men (47.3% (95% CI 45.6–49.0%)) than in women (28.3% (95% CI 26.9–29.7%); p<0.001) and increased with age: 25.8% (95% CI 23.8–27.9%) in participants <40 years old, 39.1% (95% CI 36.7–41.5%) in participants 40–49 years old, 44.7% (95% CI 42.4–46.9%) in participants 50–59 years old and 44.0% (95% CI 42.1–45.9%) in participants ⩾60 years old (p-value for trend <0.001). Prevalence of hypersomnolence (positivity of category 2) was 14.6% (95% CI 13.8–15.5%). It was lower in men (11.1% (95% CI 9.9–12.3%)) than in women (17.8% (95% CI 16.6–19.1%); p<0.001) and decreased with age: 17.0% (95% CI 15.3–18.9%) in participants <40 years old, 15.6% (95% CI 13.9–17.7%) in participants 40–49 years old, 14.2% (95% CI 12.6–16.0%) in participants 50–59 years old and 10.7% (95% CI 9.4–12.3%) in participants ⩾60 years old (p-value for trend <0.001). Characteristics of participants according to severe snoring and hypersomnolence are presented in supplementary table S4.

In multivariate analysis (table 2), heavy snoring was associated with male sex, higher age, lower educational level, smoking, lower level of physical activity, depressive symptoms and living in a couple. Hypersomnolence was associated with female sex, younger age, previous cardiovascular events, a low educational level, smoking status, the absence of alcohol consumption, a low level of physical activity and depressive symptoms. Similar associations were observed whether or not the model was further adjusted for obesity, except for the association with previous cardiovascular events which became non-significant for both symptoms. Obesity was also associated with snoring and hypersomnolence.

Discussion

Our study assessed the prevalence and determinants of treated sleep apnoea and OSA as predicted by a positive Berlin Questionnaire in the French general population; data from each participant were weighted following a modelling process that allows to extend conclusions of the study to the French general population aged 18–69 years in the selected departments of CONSTANCES [28, 29, 31]. Our results show that 3.5% had treated sleep apnoea and 18.1% had a positive Berlin Questionnaire. OSA and its cornerstone symptoms were more prevalent in older individuals, those with poorer health behaviours and socioeconomic conditions, and those with depressive symptoms.

The first report of sleep disordered breathing prevalence, published in 1993, was based on the Wisconsin Cohort Study, and reported a prevalence of 4% in men and 2% in women [3]. Since then, studies using various screening methodologies have reported a higher prevalence of the disorder. In 2001, Durán *et al.* [13] reported a prevalence of mild sleep disordered breathing (AHI ⩾5 events·h^{-1}, based on polysomnography) of 26% in men and 28% in women in the general population of the Basque country in

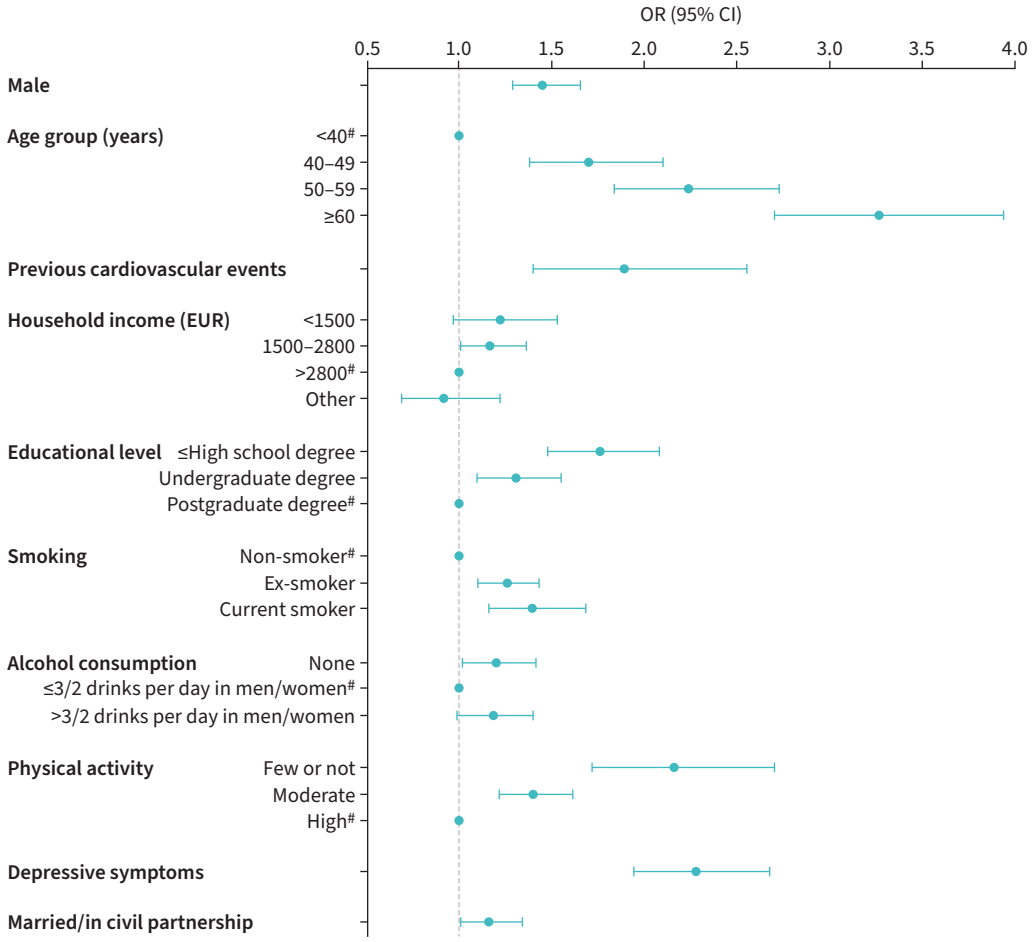

FIGURE 2 Associations between each variable and risk of obstructive sleep apnoea. Results are adjusted for age, sex, previous cardiovascular events, household income, educational level, smoking status, alcohol consumption, physical activity, depressive symptoms and marital status. #: reference.

Spain. In 2010, with the same recording method and threshold, a study among a representative sample of Sao Paulo (Brazil) inhabitants found a prevalence of 47% in men and 31% in women [15]. More recently, the HypnoLaus cohort reported a prevalence of moderate-to-severe sleep disordered breathing (AHI ⩾15 events·h^{-1}) that reached 23% (95% CI 21–26%) in women and 50% (95% CI 47–53%) in men [5]. A population-based study conducted in 27 210 adults in Canada, based on the STOP-Bang questionnaire, showed that one in five adults might suffer from sleep disordered breathing [32]. In a literature-based analysis published in 2019, Benjafield *et al.* [9] estimated that OSA affected nearly 1 billion individuals worldwide, with a prevalence exceeding 50% in some countries, and concluded that effective diagnostic and treatment strategies were needed to minimise the burden of this disorder. Noteworthy, European countries with specific estimates include Spain published in 2001 [13], Poland in 2008 [33], Switzerland in 2015 [5] and Germany in 2018 [34], with respective cohort sizes of 2148, 676, 2121 and 1208 subjects. Our study showing an overall OSA prevalence of 20.9% in the French adult population, with 24.1% in men and 18.0% in women, in a large contemporary cohort representative of the French general population adds to the existing knowledge regarding the prevalence of OSA in Western Europe.

The prevalence of heavy snoring and hypersomnolence was 37.2% and 14.6%, respectively. A smaller French study using the Berlin Questionnaire among 776 hospital health workers found similar results regarding OSA and snoring (prevalence of 23.3% and 39.7%, respectively), while the prevalence of hypersomnolence was somewhat higher (20.3%) [11]. In the only previous study assessing the prevalence of symptoms of OSA in the French general population in 2008, Fuhrman *et al.* [6] found that 30% of the adult general population reported frequent snoring and 12% reported having non-restorative sleep. Although symptoms were defined in a different manner, these data suggest that the prevalence of snoring and hypersomnolence (and thereby of OSA) may have increased over the past decade.

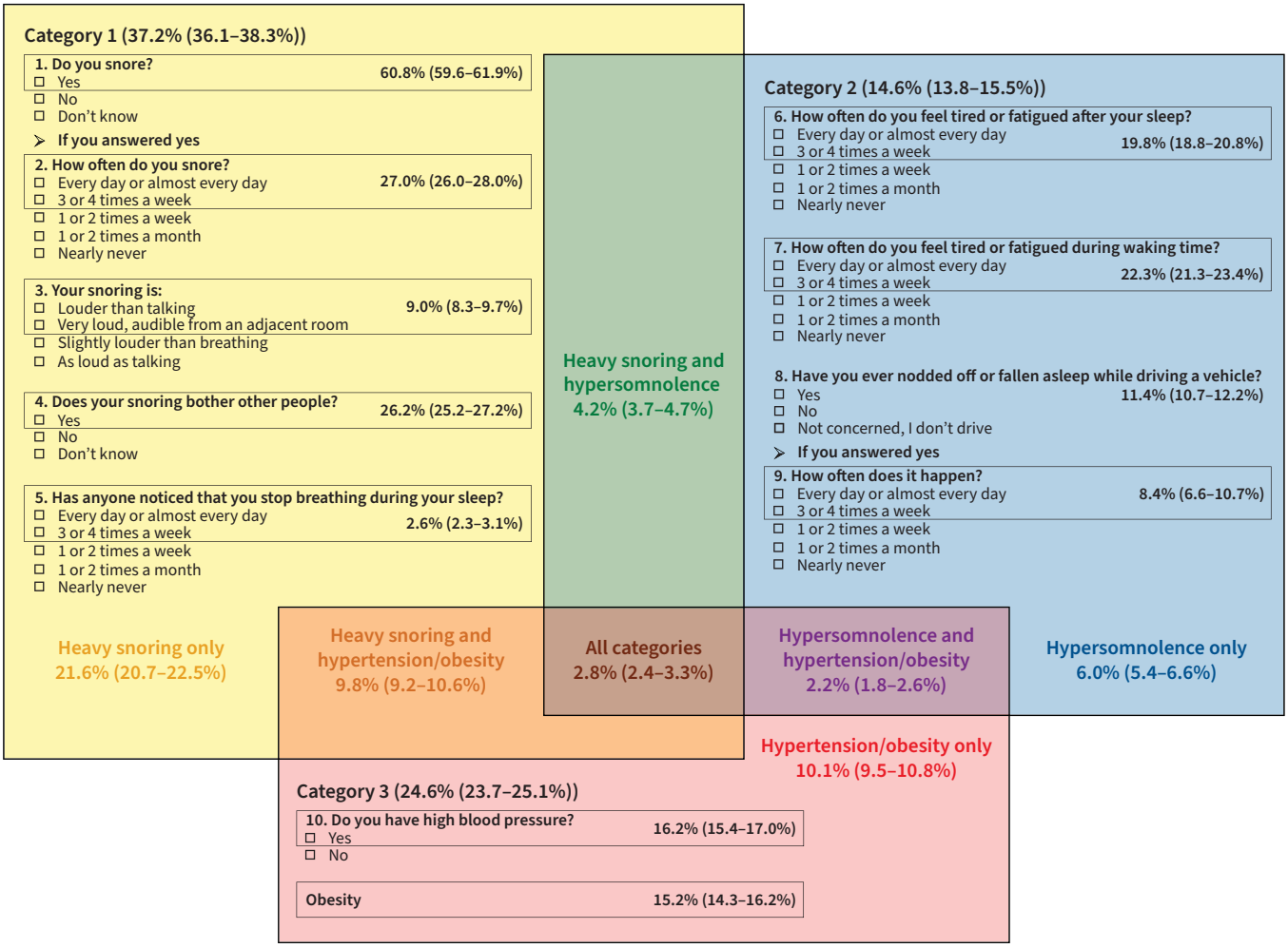

FIGURE 3 Results of the items and categories of the Berlin Questionnaire. Weighted percentages (95% CI) refer to the number of participants who checked the items or the combination of items among the 19 543 participants. Any checked item in a framed area yields 1 point except for question 5 that yields 2 points; categories 1 and 2 are considered as positive if their total score is ⩾2 points, category 3 is defined as positive if its total score is 1 point (either high blood pressure or obesity). Subjects with in at least two positive categories have a positive Berlin Questionnaire and are considered at high risk for obstructive sleep apnoea.

Besides recognised risk factors (male sex, age and obesity) [6, 35, 36], our study revealed that OSA and heavy snoring were associated with a low educational level, smoking, a lower level of physical activity and depressive symptoms. Although there is biological plausibility for a causal role of smoking in OSA, it is not established as a risk factor because of discrepant results [37]. To the best of our knowledge, educational level has not previously been shown to be independently associated with OSA. Lack of physical activity has been shown to be associated with OSA, independently of measures of body habitus [38]. Previous studies have suggested a bidirectional association between depression and sleep apnoea [39–42]. Our results are in accordance with a recent report, which used similar tools (Berlin Questionnnaire and CES-D), indicating that depression, anxiety and co-occurrence of both were associated with an increased risk of OSA [43].

Association between OSA or snoring and marital status could reflect a reporting bias [44].

In our cohort, as well as in previous studies [3, 10], hypersomnolence was more frequent in women. In addition, we found that hypersomnolence decreased with age, which might reflect an adjustment of the perception of "acceptable" modifications of sleep and fatigue with ageing [45–47]. The association of hypersomnolence with the absence of alcohol consumption may be explained by the fact that this group includes abstainers, who quit drinking due to health reasons, a well-described paradox in epidemiological studies [48].

TABLE 2 Associations between each variable and risk of heavy snoring or hypersomnolence

	Model 1[#]		Model 2[¶]	
	Heavy snoring OR (95% CI)	Hypersomnolence OR (95% CI)	Heavy snoring OR (95% CI)	Hypersomnolence OR (95% CI)
Male	2.21 (2.00–2.44)	0.69 (0.59–0.80)	2.25 (2.03–2.49)	0.69 (0.59–0.81)
Age group (years)				
<40	Reference	Reference	Reference	Reference
40–49	1.59 (1.37–1.85)	0.90 (0.73–1.10)	1.55 (1.33–1.80)	0.87 (0.71–1.07)
50–59	2.06 (1.77–2.39)	0.72 (0.59–0.89)	1.98 (1.70–2.30)	0.70 (0.57–0.86)
⩾60	1.94 (1.68–2.24)	0.59 (0.47–0.73)	1.85 (1.60–2.15)	0.57 (0.45–0.71)
Previous cardiovascular events	0.97 (0.71–1.33)	1.68 (1.03–2.71)	0.92 (0.68–1.25)	1.61 (1.00–2.63)
Household income (EUR)				
<1500	0.83 (0.68–1.02)	1.10 (0.84–1.45)	0.81 (0.66–0.99)	1.09 (0.83–1.43)
1500–2800	0.98 (0.87–1.12)	1.16 (0.96–1.40)	0.97 (0.85–1.10)	1.15 (0.95–1.39)
>2800	Reference	Reference	Reference	Reference
Other	0.81 (0.63–1.03)	1.29 (0.91–1.83)	0.80 (0.63–1.03)	1.27 (0.89–1.82)
Educational level				
⩽High school degree	1.13 (0.99–1.29)	1.51 (1.22–1.87)	1.08 (0.94–1.24)	1.47 (1.18–1.82)
Undergraduate degree	1.23 (1.08–1.39)	1.21 (0.98–1.50)	1.21 (1.06–1.38)	1.21 (0.98–1.49)
Postgraduate degree	Reference	Reference	Reference	Reference
Smoking				
Non-smoker	Reference	Reference	Reference	Reference
Ex-smoker	1.34 (1.20–1.49)	1.10 (0.93–1.29)	1.33 (1.20–1.48)	1.09 (0.93–1.29)
Current smoker	1.46 (1.24–1.70)	1.56 (1.26–1.92)	1.47 (1.26–1.73)	1.57 (1.27–1.94)
Alcohol consumption				
None	0.90 (0.79–1.04)	1.43 (1.19–1.71)	0.88 (0.77–1.02)	1.41 (1.17–1.69)
⩽3/2 drinks per day in men/women	Reference	Reference	Reference	Reference
>3/2 drinks per day in men/women	1.13 (0.97–1.31)	1.00 (0.80–1.25)	1.13 (0.97–1.31)	1.00 (0.80–1.25)
Physical activity				
Few or not	1.29 (1.06–1.56)	1.50 (1.13–2.00)	1.21 (1.00–1.48)	1.44 (1.08–1.92)
Moderate	1.13 (1.01–1.27)	1.17 (0.96–1.42)	1.09 (0.97–1.23)	1.14 (0.94–1.38)
High	Reference	Reference	Reference	Reference
Depressive symptoms	1.36 (1.17–1.59)	3.84 (3.23–4.56)	1.33 (1.14–1.55)	3.79 (3.20–4.50)
Married/in civil partnership	1.44 (1.28–1.62)	0.89 (0.75–1.05)	1.43 (1.27–1.61)	0.88 (0.74–1.04)
Obesity			1.78 (1.52–2.07)	1.44 (1.18–1.76)

[#]: adjusted for age, sex, previous cardiovascular events, household income, educational level, smoking status, alcohol consumption, physical activity, depressive symptoms and marital status; [¶]: adjusted for age, sex, previous cardiovascular events, household income, educational level, smoking status, alcohol consumption, physical activity, depressive symptoms, marital status and obesity.

While OSA is recognised as a major health hazard, it remains majorly underdiagnosed. We found that despite 18.1% of the French general population being at high risk of OSA, the prevalence of treated sleep apnoea was only 3.5%, suggesting that the vast majority of people with OSA are not diagnosed, and obviously not treated. Our study suggested an even greater underdiagnosis of OSA among women, as previously reported [8, 49], suggesting under-complaint for sleep apnoea symptoms and/or less attention paid by healthcare providers to these symptoms among women [50]. Interestingly, Young *et al.* [8] estimated that 93% of women and 82% of men with moderate-to-severe OSA were unaware of their disorder and reported the same risk factors of underdiagnosis. Underdiagnosis is therefore a major issue in the general population, but also exists in groups at high risk. For example, in a cohort of patients with newly diagnosed heart failure, Javaheri *et al.* [51] found that OSA was rarely searched for, and consequently subjects were underdiagnosed and not treated. Meanwhile, the few subjects who were tested, diagnosed and treated for OSA had a much better 2-year survival rate.

Given the burden of undiagnosed sleep apnoea, such data and our study support the need for sleep apnoea awareness campaigns such as the one implemented in Finland between 2001 and 2010. A recent analysis of the impact of this campaign showed a massive and continuous increase in outpatient visits for sleep apnoea, together with a decrease in apnoea-related health costs attributable to better and earlier diagnosis [52].

The main limitation of our analysis is that we diagnosed a high risk of OSA using the Berlin Questionnaire and not OSA itself using the gold standard polysomnography. However, polysomnography is not feasible

in large epidemiological studies due to its high cost and limited availability, and is generally performed in subgroups of patients known to be at high risk [26]. Among screening questionnaires, even though STOP-Bang and NoSAS scores are more sensitive than the Berlin Questionnaire [53, 54], the latter (which does not include age and gender) was used here according to our study objective, to describe the gender and age distribution of OSA as well as its determinants in a multivariate analysis adjusted on age and sex. The strengths of our study are the large population-based sample provided by the CONSTANCES cohort and the use of weighting coefficients at inclusion and follow-up. These weights allow an estimate of prevalence of treated sleep apnoea, high risk of OSA and its symptoms among the French adult population aged 18–69 years in the selected departments of CONSTANCES and covered by the general health insurance scheme. Using the Berlin Questionnaire in such a large sample allowed us to describe in depth the prevalence and risk factors of OSA symptoms. Regarding these points, our study provided recent, strong and unique data on OSA in the French adult population.

Conclusions

Symptoms that predict a high risk of OSA were found in one in five participants in a French population-based cohort. This highly prevalent disorder is underdiagnosed: beyond well-known risk factors such as obesity, more attention should be given to less recognised high-risk groups such as depressive people, individuals with unhealthy behaviours and socioeconomic conditions.

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