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Prevalence of sleep-disordered breathing in an African general population: The Benin Society and Sleep (BeSAS) study



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Summary

Background Data on the prevalence of sleep-disordered breathing (SDB) in the African general population are scarce, and a better understanding is urgently needed. Our study aimed to objectively determine the prevalence of, and factors associated with, SDB in a large sample in Benin, west Africa.

Methods In the Benin Society and Sleep (BeSAS) cross-sectional study, participants aged 25 years and older were recruited from both urban and rural areas. Rural participants were recruited from Tanve, a village located 200 km north of Cotonou, and urban participants were recruited from Cotonou. The participants underwent respiratory polygraphy at home using a type-3 device that measures airflow through a nasal pressure sensor, respiratory effort (thoracic movement), and pulse oximetry. Clinical and morphometric data were also collected. SDB severity categories were defined according to the apnoea–hypopnoea index (AHI), with mild-to-severe SDB (AHI ≥ 5 /h), moderate-to-severe SDB (AHI ≥ 15 /h), and severe SDB (AHI ≥ 30 /h).

Findings The study was completed from April 4, 2018 to Jan 15, 2021. Of 2909 participants recruited in the BeSAS study, 2168 (74.5%) underwent respiratory polygraphy. For the 1810 participants with complete polygraphic data (mean age 46 years, SD 15; 1163 [64.2%] women), the prevalence of mild-to-severe SDB (AHI ≥ 5 /h) was 43.2% (95% CI 40.9–45.5), of moderate-to-severe SDB (AHI ≥ 15 /h) was 11.6% (10.2–13.1), and of severe SDB (AHI ≥ 30 /h) was 2.7% (2.0–3.5). Factors independently associated with SDB were advanced age, male sex, large neck circumference, abdominal obesity, overweight or obesity, and snoring. After multivariable adjustment, severe SDB was independently associated with hypertension in women (odds ratio 3.99, 95% CI 1.04–15.33; $p_{\text{trend}}=0.044$), but not in men (odds ratio 0.67, 0.22–2.05; $p_{\text{trend}}=0.63$).

Interpretation The BeSAS study provides the first large-scale objective evaluation of SDB prevalence and associated factors in Africa. The high prevalence of SDB identified should stimulate the development of public health policies to prevent and treat this condition in African countries.

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Introduction

Sleep-disordered breathing (SDB) is a major public health concern that remains under recognised in resource-limited settings.^{1–4} Worldwide prevalence of SDB is increasing, in parallel with the upward epidemic curve of obesity, a major SDB risk factor.^{2,5} SDB is characterised by recurrent episodes of apnoea and hypopnoea, which result in intermittent hypoxaemia and sleep disruption.⁶ In addition to its immediate consequences (excessive daytime sleepiness and fatigue), SDB has been linked, in the long term, to a higher risk of chronic diseases such as hypertension, diabetes, metabolic syndrome, cardiovascular diseases, depression, and cancer,⁷ and increased all-cause mortality.⁸

It was recently estimated that 425 million adults (aged 30–69 years) worldwide have moderate-to-severe SDB, with a prevalence exceeding 50% in some countries.⁹ However, most of the available data on the prevalence of SDB, its risk factors, and health consequences come

from studies done in North America, Europe, and Asia, whereas data from the African continent are rare.^{2,9,10} Indeed, only a few studies have attempted to estimate the prevalence of SDB in Africa, but they were based on self-administered questionnaires, or were done in small-sized clinical populations referred for suspected SDB.^{11–14} A study was conducted in a rural setting in South Africa using polysomnographic-derived data. However, this study only had a small sample population ($n=75$), precluding to estimate the precise SDB prevalence in that population.¹⁵ Therefore, data are scarce on the prevalence of SDB in the African general population and a better understanding is urgently needed.

Moreover, epidemiological studies have suggested that the prevalence of SDB might vary by patient ethnicity. Data from both the Multi-Ethnic Study of Atherosclerosis¹⁶ and the Jackson Heart Sleep Study¹⁷ done in the USA suggested that SDB is more prevalent, and presumably more severe, in African Americans than White

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Research in context**Evidence before this study**

We did a systematic review up to March, 2018, on PubMed, with the terms “sleep apnea”, “sleep apnoea”, “sleep disordered breathing”, “Africa”, “African population”, and “prevalence”, with no language restrictions. We found no previous study that assessed the prevalence of sleep disordered-breathing (SDB) in Africa.

Added value of this study

There was a high prevalence of SDB (apnoea–hypopnoea index ≥ 5 /h) in Africa (43.2% [95% CI 40.9–45.5]), which was similar to comparable studies from other continents. The main risk factors

for SDB in this population were advanced age, male sex, large neck circumference, abdominal obesity, overweight or obesity, and snoring. There was also an association between increasing SDB severity and hypertension in women, but not in men.

Implications of all the available evidence

This study objectively measured SDB prevalence from a large random convenience sample in Benin, which will facilitate better overall estimates of SDB prevalence and pave the way for further epidemiological research on sleep in Africa. The high prevalence of SDB in this study should stimulate the development of public health policies to prevent and treat SDB in African countries.

Americans.^{16,17} However, this assumption of higher SDB prevalence in populations of African descent has not yet been confirmed by studies done in African populations living on the African continent. Therefore, the objective of the Benin Society and Sleep (BeSAS) study was to assess the prevalence, risk factors, and associated comorbidities of SDB, such as hypertension and diabetes, in a large national cohort in Benin.

Methods**Study design and setting**

BeSAS was a cross-sectional study that relied on a large national cohort that used a random convenience sampling approach to capture a diverse sample. The study was completed in Benin, west Africa (a low-income country with approximately 12 million inhabitants). The research project was approved by the National Ethics Committee of Benin (reference number 45; Oct 25, 2017) with regular annual approval renewal throughout its course.

Participants

In Benin, 51.6% of the total population lives in rural areas,¹⁸ thus participants were recruited from both the rural and urban general population. Rural participants were recruited from Tanve, a village of 2721 inhabitants, located 200 km north of Cotonou. This village is typical of African rural areas, with little access to electricity, internet, or modern lifestyle, minimal road traffic, with agriculture as the primary activity, and no modern buildings. Residents of Tanve already participate in a prospective population-based cohort, the Tanve Health Study (TAHES), set up in 2015 with the aim of evaluating the incidence of cardiovascular risk factors in an African rural population.¹⁹ A preliminary survey done at the beginning of the TAHES study reported that the total population aged 25 years and older comprised 1308 individuals. For the BeSAS study, the goal was to include at least 90% of that adult population, giving a sample size of 1177 people, rounded to 1200 participants.

The urban population was selected from Cotonou, the economic capital of Benin, with 685 000 inhabitants, which has all the main characteristics of African urban settings

(high population density, modern marketplaces, modern buildings, and access to electricity and the internet). To match the number of participants recruited in the rural area (48% of Benin population lives in cities), the goal was to include at least 1200 individuals from the urban area.

The average household size in Cotonou is four individuals aged 25 years and older (2013 census). Thus, it was estimated that at least 300 households needed to be included to reach the recruitment target. These households were randomly selected from a representative area of Cotonou, the third subcity. We randomly selected nine districts out of 13 comprising this subcity. The number of households to be recruited in each district was determined according to its size (full description of the districts selection process in the appendix p 3). We then determined for each district the ratio between the number of households to be recruited and the total number of households of the district. If this ratio was for example one of five, the field investigators contacted every fifth household. The initial household of each district was randomly selected by lottery method. This method consists of randomly choosing the first household in a district by numbering slips of paper of same size, shape, and colour with numbers ranging from 1 to n, where n is equal the ratio between number of households in the district and number of households to be selected. Then, the papers were folded and mixed up in a box. A blindfold selection of a paper was made by an investigator to establish the first household to be selected. At each selected household, all consenting adults aged 25 years or older living in Cotonou for at least three months were recruited. In the case in which no participant could be recruited in a selected household, the sampling process continued to the next household.

Participants were enrolled on a voluntary basis and provided written informed consent. If a participant was unable to read or write, a family member able to read was asked to assist with providing information.

Procedures

Respiratory polygraphy was done using ApneaLink Plus (ResMed, Bella Vista, Australia) devices. This type-3

See Online for appendix

portable recorder measures airflow through a nasal pressure sensor, respiratory effort (thoracic movement), and pulse oximetry (Nonin; Nonin Medical, Plymouth, MA, USA). Participants were provided with one of these devices that was set up in their home between 20:00 and 22:00 by one of the four trained research assistants, who returned the next morning to collect the device. The equipment was set for a fixed period of the night, but participants were asked to provide lights-off and lights-on times. All polygraphy data were transformed into European Data Format files to allow reading in Noxturnal software (version 6.2; Nox Medical, Reykjavik, Iceland). The sleep recordings were then manually scored by a certified sleep physician (APW) with more than 10 years of experience in respiratory sleep medicine who was unaware of the participant's data. Only polygraphy data with at least 4 h of recording with airflow, pulse oximetry, and respiratory effort signal were considered valid and included in the analysis. Respiratory events were scored according to the 2012 American Academy of Sleep Medicine manual.²⁰ Sleep apnoea was defined as a reduction of 90% or more in airflow for at least 10 s. Hypopnoea was defined as an airflow reduction of at least 30% for 10 s or more during sleep associated with a desaturation of at least 3%. The apnoea-hypopnoea index (AHI) was calculated as the sum of all apnoea and hypopnoea episodes divided by the estimated sleep time based on participant reporting. SDB was defined as mild to severe (AHI ≥ 5 /h), moderate to severe (AHI ≥ 15 /h), or severe (AHI ≥ 30 /h).

Demographic data (age, sex, and area of residence), alcohol intake, and smoking habits were collected by self-declaration. Height was measured with a rigid gauge and weight was measured in a standing position, with as little clothing as possible and without shoes, using mechanical devices (Seca; Hamburg, Germany). Nutritional status was assessed using body-mass index (BMI), calculated as weight divided by height squared. Healthy BMI was defined as less than 25 kg/m², overweight as 25 kg/m² or higher but less than 30 kg/m², and obesity as 30 kg/m² or higher. Neck and waist circumferences were measured using standardised procedures. Abdominal obesity was defined as waist circumference of 102 cm or more in men and 88 cm or more in women. Blood pressure was measured three times on both arms (Spengler; Aix-en-Provence, France) and the average of the last two readings for each arm was calculated. Hypertension was defined as systolic blood pressure of at least 140 mm Hg, diastolic blood pressure of at least 90 mm Hg on at least one arm, or current use of anti-hypertensive drugs. A capillary fasting glycaemia test was done for each subject using a glucometer (Accucheck Performa; Roche Diagnostics, Basel, Switzerland). Diabetes was defined as a self-reported medical history of diabetes or capillary fasting glycaemia of 7 mmol/L or more.

The Pittsburgh sleep quality index (PSQI) was used to assess subjective sleep quality over a 1-month time

period.²¹ Total scores range from 0 to 21; a score of 6 or higher indicates poor sleep quality. Daytime sleepiness was determined using the Epworth sleepiness scale (ESS),²² with a total score of 0 to 24 and excessive daytime sleepiness indicated by a score of 11 or higher. ESS was only calculated if the participants were able to answer the eight questions of the scale. Two other scales were used as predictors of sleep apnoea, the neck obesity snoring age sex (NoSAS) score and the Berlin questionnaire. The NoSAS score ranges from 0 to 17 and a score of 8 or higher indicates a high risk of obstructive sleep apnoea. A Berlin questionnaire score of at least 2 is considered to indicate a high risk of sleep apnoea. Most clinical data were collected during face-to-face interviews using KoBoToolbox (Harvard Humanitarian Initiative, Cambridge, MA, USA) software on digital tablets by trained and experienced interviewers.

Statistical analysis

Continuous variables were summarised as medians (IQR) or mean (SD), and categorical variables as proportions. Between-group comparisons were done using a χ^2 test, Kruskal-Wallis test, or Wilcoxon's rank-sum test, as appropriate. Baseline characteristics of participants who underwent polygraphy were compared with participants in the BeSAS study with no valid polygraphy data, and the effect size of any between-group differences found was evaluated using Cohen's *d* for continuous variables and Cramer's *v* for categorical variables.

Comparison of prevalence by age groups, sex, nutritional status, and area of residence were done using multiple proportion comparison tests.

Ordinal logistic regressions were used to estimate the factors associated with SDB. Individuals with missing

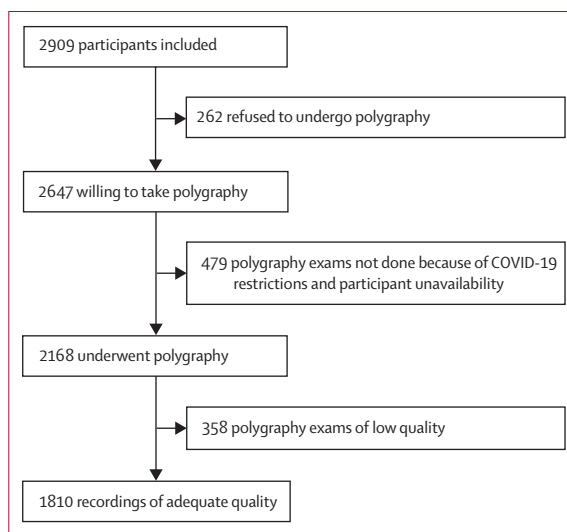


Figure 1: Participant inclusion and exclusion criteria

Data were not collected on the number screened. We included all consenting eligible people in a chosen household.

	All	No SDB	Mild SDB	Moderate SDB	Severe SDB	p value
Number of cases	1810 (100.0%)	1029 (56.9%)	572 (31.6%)	161 (8.9%)	48 (2.7%)	..
Sex	..	..	..	..	..	<0.0001
Male	647 (35.7%)	315 (30.6%)	238 (41.6%)	71 (44.1%)	23 (47.9%)	..
Female	1163 (64.3%)	714 (69.4%)	334 (58.4%)	90 (55.9%)	25 (52.1%)	..
Area of residence						
Rural	955 (52.8%)	604 (58.7%)	273 (47.7%)	67 (41.6%)	11 (22.9%)	<0.0001
Urban	855 (47.2%)	425 (41.3%)	299 (52.3%)	94 (58.4%)	37 (77.1%)	..
Age, years	43 (34-55)	39 (32-50)	46 (37-58)	54 (43-64)	55 (49-64)	<0.0001
Age category	..	..	..	..	..	<0.0001
<40 years	767 (42.4%)	548 (53.3%)	181 (31.6%)	34 (21.1%)	4 (8.3%)	..
40-59 years	702 (38.8%)	335 (32.6%)	273 (47.7%)	69 (42.9%)	25 (52.1%)	..
60 years	341 (18.8%)	146 (14.2%)	118 (20.6%)	58 (36.0%)	19 (39.6%)	..
BMI, kg/m ²	23.6 (20.5-27.8)	22.3 (19.7-25.7)	25.3 (21.9-29.6)	26.4 (22.6-30.8)	31.6 (27.2-37.8)	<0.0001
BMI categories	..	..	..	..	..	<0.0001
Healthy	1080 (59.7%)	721 (70.1%)	282 (49.3%)	67 (41.6%)	10 (20.8%)	..
Overweight	420 (23.2%)	213 (20.7%)	154 (26.9%)	47 (29.2%)	6 (12.5%)	..
Obese	310 (17.1%)	95 (9.2%)	136 (23.8%)	47 (29.2%)	32 (66.7%)	..
Neck circumference	34.0 (32.0-37.0)	34.0 (32.0-36.0)	35.0 (33.0-38.0)	36.0 (34.0-38.5)	39 (36.5-41.0)	<0.0001
Abdominal obesity	673 (37.2%)	300 (29.2%)	255 (44.6%)	82 (50.9%)	36 (75.0%)	<0.0001
Alcohol use	200 (11.1%)	91 (8.8%)	80 (14.0%)	19 (11.8%)	10 (20.8%)	0.0020
Current smoking	146 (8.1%)	71 (6.9%)	53 (9.3%)	16 (9.9%)	6 (12.5%)	0.14
Snoring	492 (27.2%)	200 (19.4%)	186 (32.5%)	69 (42.9%)	37 (77.1%)	<0.0001
Hypertension	836 (46.2%)	392 (38.1%)	302 (52.8%)	104 (64.6%)	38 (79.2%)	<0.0001
Diabetes	74 (4.2%)	26 (2.6%)	32 (5.8%)	12 (7.8%)	4 (8.7%)	<0.0001
PSQI ≥5	754 (41.7%)	394 (38.3%)	270 (47.2%)	70 (43.5%)	20 (41.7%)	0.0070
NoSAS ≥8	223 (12.3%)	47 (4.6%)	92 (16.1%)	56 (34.8%)	28 (58.3%)	<0.0001
Berlin score ≥2	259 (14.3%)	85 (8.3%)	104 (18.2%)	42 (26.1%)	28 (58.3%)	<0.0001
ESS score ≥11	302 (16.7%)	47 (4.6%)	19 (24.7%)	8 (47.1%)	1 (16.7%)	0.011
Reported sleep time in hours*	7.2 (1.3)	7.1 (1.2)	7.0 (1.4)	6.8 (1.5)	7.0 (1.2)	0.38
AHI, events per hour	4.2 (2.0-8.1)	2.1 (1.2-3.3)	7.4 (6.1-9.9)	18.6 (16.2-21.7)	36.9 (32.2-50.8)	<0.0001
OAI, events per hour	0.7 (0.2-1.7)	0.4 (0.1-1.0)	1.0 (0.4-2.2)	2.2 (0.7-5.1)	8.8 (3.7-20.5)	<0.0001
CAI, events per hour	0 (0-0.2)	0 (0-0.1)	0 (0-0.2)	0.2 (0-0.6)	0.6 (0-3.4)	<0.0001
MAI, events per hour	0	0	0	0 (0-0.2)	0.2 (0-0.5)	<0.0001
HI, events per hour	2.9 (1.0-6.4)	1.2 (0.5-2.2)	5.8 (4.7-7.8)	15.2 (12.8-17.2)	25.4 (18.4-33.0)	<0.0001
Mean SpO ₂	96.2 (95.1-97.1)	96.8 (96.1-97.4)	95.6 (94.6-96.4)	94.2 (92.7-95.3)	93.4 (91.8-94.3)	<0.0001
Minimum SpO ₂	87.0 (81.0-91.0)	91.0 (83.0-93.0)	85.0 (81.0-89.0)	81.0 (77.0-85.0)	75.0 (66.0-80.0)	<0.0001
ODI 3%, events per hour	4.5 (2.0-9.1)	2.3 (1.2-3.6)	8.2 (6.4-10.8)	19.9 (17.1-23.1)	37.0 (32.6-51.4)	<0.0001
Time spent with SpO ₂ ≤90%	0 (0-0.7)	0 (0-0.1)	0.1 (0-0.8)	1.4 (0.4-4.9)	5.1 (2.3-14.7)	<0.0001

Data are presented as median (IQR), mean (SD), or n (%). ESS questionnaire data were usable for 201 (11.1%) of 1810 participants. N=1810 for all variables except for neck circumference (n=1805), diabetes (n=1770), and ESS (n=201). SDB=sleep-disordered breathing. BMI=body-mass index. PSQI=Pittsburgh sleep quality index. NoSAS=neck obesity snoring age index score. ESS=Epworth sleepiness scale. AHI=apnoea-hypopnoea index. OAI=obstructive apnoea index. CAI=central apnoea index. MAI=mixed-apnoea index. HI=hypopnoea index. SpO₂=pulse oximetry oxygen saturation. ODI=oxygen desaturation index. *Sleep time was estimated on the basis of lights-off and lights-on times reported by the participants.

Table 1: Baseline demographic data, clinical characteristics, and polygraphic data of the BeSAS study population according to SDB severity

data (five individuals for neck circumference and 40 individuals for diabetes) were excluded. Assumption of linearity for each continuous covariate was checked using locally weighted scatterplot smoothing. In the case of non-linearity, continuous variables were transformed into categorical variables on the basis of clinically relevant cutoffs. We identified important covariates by analysing contingency tables and fitting univariate ordinal logistic regression. We selected all the variables with p<0.20

along with the variables of known clinical importance. We did a multivariable ordinal logistic-regression analysis using the STATA command `ologit`. Results are presented in the form of proportional odds ratio (OR) and corresponding 95% CIs. To assess collinearity between covariates, the variance inflation factor (VIF) was calculated for each covariate. All covariates had a VIF of 5 or less, suggesting no collinearity. No interaction term was found between sex and SDB.

To estimate the association between SDB severity and the risk of associated comorbidities such as diabetes and hypertension, the sample was divided into four groups on the basis of usual AHI cutoffs (no SDB <5/h, mild SDB 5–14/h, moderate SDB 15–29/h, and severe SDB ≥30/h). Several logistic-regression models were applied. Model 1 was adjusted for age and area of residence, model 2 was additionally adjusted for alcohol and tobacco consumption, model 3 was additionally adjusted for BMI, and model 4 was additionally adjusted for neck circumference and abdominal obesity. Considering previously reported sex differences in the association between SDB and comorbidities, we further did a sex-stratified analysis. The different models were compared with the likelihood ratio test. Two-tailed $p < 0.05$ was considered statistically significant.

All statistical analyses were done using Stata version 14 (College Station, TX, USA) and R (version 4.1.1) on R Studio (version 1.4.1717).

Role of the funding sources

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

The study was done between April 4, 2018, and Jan 15, 2021. Of 2909 participants recruited in the BeSAS study, 2168 (74.5%) underwent respiratory polygraphy. Among them, 1772 were of adequate quality and 396 were not. Among the 396 that were not, 203 were repeated and only 38 were of good quality, making the total number of valid tests 1810 and 358 tests of low quality. Therefore, no valid recording was obtained from 358 participants and these individuals were excluded from further analysis (figure 1).

Demographic and clinical characteristics and description of polygraphic data for the 1810 participants with valid polygraphy are shown (table 1). The population was predominantly women, more than half were from rural areas, and the majority were aged 40 years or older (table 1). Participants who were overweight or obese represent 40.3% of the sample. Hypertension was found in 836 (46.2%) participants and diabetes in 74 (4.2%) participants. Median AHI was 4.2 (IQR 2.0–8.1; table 1).

Compared with participants in the BeSAS study who did not have polygraphy data, participants with valid polygraphy data were similar in terms of age, snoring, PSQI, alcohol and smoking habits, Berlin questionnaire, and NoSAS scores. There were some slight between-group differences in sex, neck circumference, waist circumference, smoking, and ESS, but Cohen's *d* (for continuous variables) and Cramer's *v* (categorical variables) values suggested a small effect size (appendix p 5).

The prevalence was 43.2% (95% CI 40.9–45.5) for mild-to-severe SDB, 11.6% (10.2–13.1) for moderate-to-severe SDB, and 2.7% (2.0–3.5) for severe SDB. The

prevalence was higher in men than in women for mild-to-severe SDB ($p < 0.0001$) and moderate-to-severe SDB ($p = 0.0060$; figure 2A). Individuals aged 60 years and older had a higher prevalence of SDB than younger participants in each of the SDB categories ($p \leq 0.0001$; figure 2B). In addition, SDB was more prevalent in participants living in urban versus rural areas ($p < 0.0001$; figure 2C), and there was a gradual increase in SDB prevalence with increasing BMI ($p < 0.0001$; figure 2D).

Stratified prevalences by sex and age are shown in table 2. For mild-to-severe SDB, the highest prevalence was found in the age group 60–69 years for men, whereas in women, it was the highest prevalence was found in the 50–59-year age group.

Factors associated with moderate-to-severe SDB on univariate ordinal logistic-regression analysis were older age, male sex, overweight and obesity, large neck circumference, abdominal obesity, snoring, hypertension, diabetes, smoking, alcohol consumption, and living in urban area (table 3).

Multivariate ordinal logistic regression showed a significant association between SDB and older age, overweight and obesity, large neck circumference, abdominal obesity, and snoring (table 3).

Increasing SDB severity was associated with hypertension in model 1 and model 2, with a significant p_{trend} across the disease severity categories ($p_{\text{trend}} = 0.0001$); this association was no longer significant after adjustment for BMI (model 3), and neck circumference and abdominal obesity (model 4; appendix p 4). There were no significant

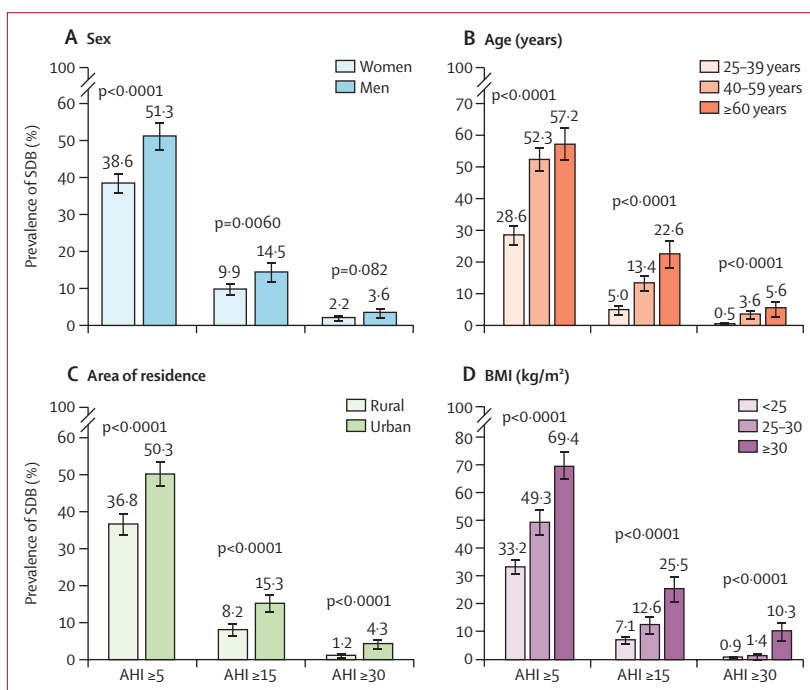


Figure 2: Prevalence of SDB

Error bars are 95% CIs. Prevalence of SDB by sex (A), age (B), area of residence (C), and nutritional status (D). AHI=apnoea-hypopnoea index. BMI=body-mass index. SDB=sleep-disordered breathing.

	Mild-to-severe SDB		Moderate-to-severe SDB		Severe SDB	
	Men	Women	Men	Women	Men	Women
25–29 years	35.5 (26.3–45.9)	16.1 (11.0–23.0)	7.5 (3.6–15.1)	3.4 (1.4–8.0)	1.1 (0.2–7.5)	0.7 (0.1–4.7)
30–39 years	39.5 (32.4–47.1)	26.6 (22.3–31.5)	8.7 (5.3–14.0)	3.1 (1.7–5.6)	0.6 (0.1–4.1)	0.3 (0.1–2.0)
40–49 years	58.2 (50.0–66.0)	40.4 (34.6–46.4)	10.3 (6.3–16.4)	10.2 (7.1–14.5)	2.1 (0.7–6.3)	2.6 (1.3–5.5)
50–59 years	60.4 (50.4–69.6)	60.0 (52.8–66.8)	21.8 (14.7–31.1)	15.8 (11.2–21.8)	7.9 (4.0–15.2)	3.7 (1.8–7.6)
60–69 years	65.4 (54.3–75.1)	53.2 (44.3–61.8)	30.9 (21.6–42.0)	23.0 (16.4–31.3)	11.1 (5.8–20.2)	5.6 (2.6–11.3)
70–79 years	62.5 (46.1–76.5)	53.7 (40.0–66.8)	20.0 (10.0–36.0)	18.5 (10.1–31.6)	..*	3.7 (0.9–14.2)
≥80 years	50.0 (23.2–76.8)	53.9 (33.8–72.7)	14.3 (2.9–48.0)	11.5 (3.5–32.1)	7.1 (0.8–44.1)	..*

Data are prevalence (95% CI). SDB=sleep-disordered breathing. *No participants in these subgroups.

Table 2: Prevalence of SDB by disease severity and 10-year increment age group in the BeSAS study

	Crude OR (95% CI)	p value	Adjusted OR (95% CI)	p value
Age, 10-year increment	1.40 (1.31–1.49)	<0.0001	1.43 (1.33–1.54)	<0.0001
Sex				
Male vs female	1.65 (1.16–2.07)	<0.0001	1.42 (1.04–1.94)	0.029
BMI categories, * kg/m ²				
25–29.99	1.93 (1.54–2.40)	<0.0001	1.36 (1.03–1.80)	0.030
≥30	4.69 (3.66–6.02)	<0.0001	2.57 (1.79–3.68)	<0.0001
Neck circumference	1.24 (1.20–1.27)	<0.0001	1.15 (1.10–1.20)	<0.0001
Abdominal obesity, yes vs no	2.28 (1.90–2.75)	<0.0001	1.45 (1.07–1.96)	0.017
Snoring, yes vs no	2.70 (2.20–3.30)	<0.0001	1.79 (1.43–2.23)	<0.0001
Hypertension, yes vs no	2.24 (1.87–2.69)	<0.0001	1.23 (0.99–1.53)	0.055
Diabetes, yes vs no	2.48 (1.61–3.80)	<0.0001	1.27 (0.81–2.00)	0.31
Alcohol use, yes vs no	1.60 (1.22–2.11)	0.0010	1.29 (0.94–1.77)	0.11
Current smoking, yes vs no	1.43 (1.03–1.97)	0.029	0.94 (0.66–1.36)	0.76
Living in urban area, vs rural	1.80 (1.50–2.16)	<0.0001	0.99 (0.80–1.22)	0.99

OR= odds ratio. BMI=body-mass index. *Reference group, BMI <25 kg/m².

Table 3: Factors associated with sleep-disordered breathing after ordinal logistic regression in the BeSAS study

associations between SDB and diabetes in any of the four models (appendix p 4).

After stratification by sex, the fully adjusted model showed a significant association between SDB and hypertension in women (OR 4.00 [95% CI 1.04–15.33]; $p_{\text{trend}}=0.044$ across SDB severity categories) but not in men (figure 3).

Discussion

To the best of our knowledge, this study is the first to report the objectively measured prevalence of SDB and its associated factors in a large sample in Africa. Our data show a high burden of SDB in an African general population, which was similar to reported prevalence rates on other continents. These data also show that the factors associated with SDB are similar to those reported in the literature.

Compared with other studies with objective measures, the prevalence rate of 43.2% found for mild-to-severe SDB in our study was similar to the prevalence of 46% (95% CI 44.4–47.4) reported in the SHIP-Trend cohort in Germany.²³ However, the prevalence for mild-to-severe

SDB in our study is lower than that reported in the HypnoLaus cohort from Switzerland (at 72%).²⁴ Still, HypnoLaus was based on an older population (median age 57 years compared with 46 years in our study), who had higher rates of obesity and a higher proportion of male individuals compared with our study. Moreover, the polysomnography recordings used in this cohort tend to provide higher AHI values than the polygraphy recordings used in BeSAS. Three decades ago, Young and colleagues²⁵ reported a lower SDB prevalence of 24% in men and 9% in women from the pioneer Wisconsin cohort study, but these results are difficult to compare with the findings of our study because of differences in respiratory event definitions and recording techniques (thermistor vs nasal pressure).

More recently, the Jackson Heart Sleep study¹⁷ was done in an African American cohort in the USA and reported a prevalence of moderate-to-severe SDB that was more than double that found in our study (23.6% vs 11.6%). However, it is worth noting that participants in the Jackson cohort were older (mean age 63.1 years) and more were obese (mean BMI 32 kg/m²) than participants in the BeSAS study (mean age 46 years, mean BMI 23.6 kg/m²). Interestingly, in our sample, the prevalence of moderate-to-severe SDB was 25.5% in participants with a BMI of at least 30 kg/m² and 22.6% in those aged at least 60 years, which is quite similar to the prevalence rate in the Jackson study. Given that most African Americans are originally from west Africa, where the BeSAS study was done, it would be interesting to do an in-depth and comprehensive comparison between the two databases and other epidemiological studies to see whether any ethnic specificity can be identified.

Our data also showed that the prevalence of SDB in men increased with age up to 60–69 years and then decreased, whereas in women the highest SDB prevalence was reached earlier (in individuals aged 50–59 years). This early rise in prevalence in women compared with other cohorts^{23,24} might be explained by the higher prevalence of obesity in women in our study and by an earlier onset of menopause in African women.²⁶ According to findings from the HypnoLaus cohort,

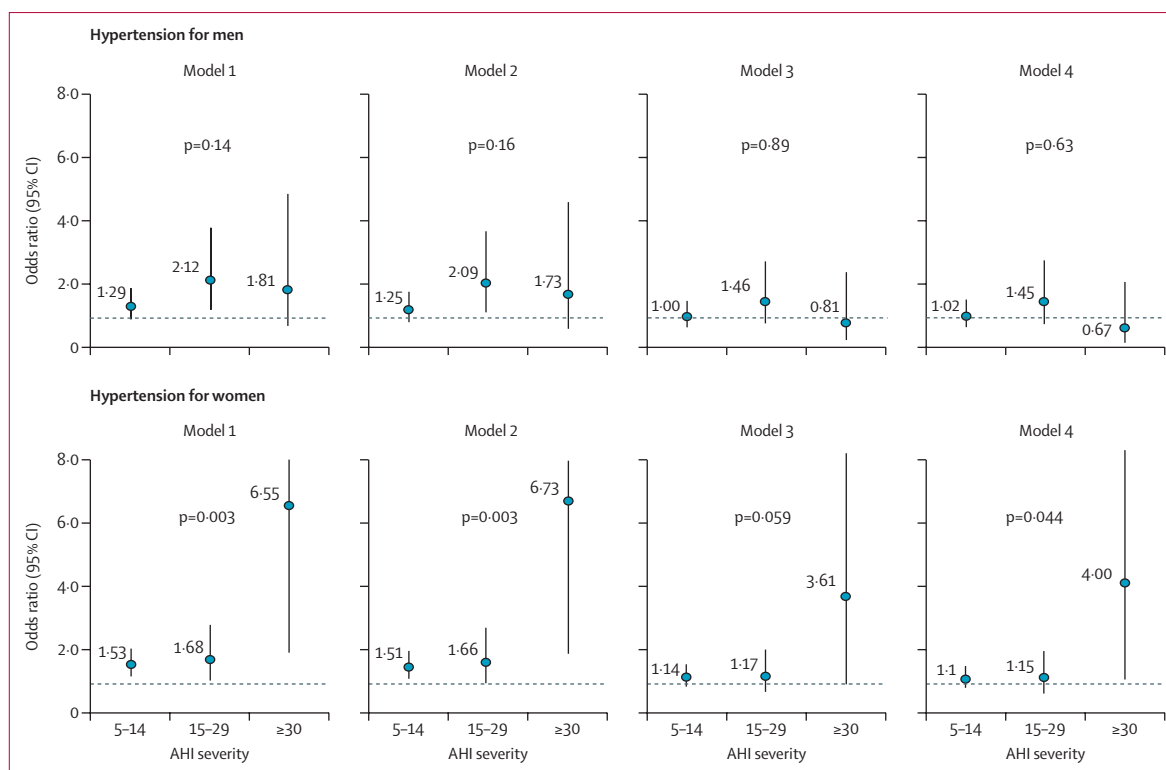


Figure 3: Estimated risk for hypertension associated with the severity of SDB and stratified by sex

Points and bars represent odds ratios and 95% CIs. AHI severity groups defined as mild (5–14 events per h), moderate (15–29 events per h), and severe (≥ 30 events per h) were compared with the reference group (< 5 events per h). p values are for trends across severity groups. Model 1 was adjusted for age and living area; model 2 was model 1 plus alcohol and tobacco consumption; model 3 was model 2 plus BMI; and model 4 was model 3 plus neck circumference and abdominal obesity. SDB=sleep-disordered breathing. AHI=Apnoea-hypopnoea index.

menopause could represent a major determinant, even more than age, for prevalence changes.²⁴

Of note, there were many parts of the ESS questionnaire that could not be answered by participants in the BeSAS study because their lifestyle differed from that of individuals from other continents. For example, a fair proportion of participants did not drive or do not go to the theatre. Therefore, we could not reliably assess the prevalence of sleep-apnoea syndrome (AHI ≥ 5 /h + excessive daytime sleepiness) in our sample. This raises the question of the reliability of this scale in African populations and other low-income areas, in which driving a car, going to the cinema, or watching TV are not common activities. It is therefore necessary to develop an alternative tool, or to adapt the ESS, to be able to accurately assess daytime sleepiness in African and similar populations.

Consistent with the findings from other epidemiological sleep studies,^{23–25} the main factors associated with SDB on univariate analyses in our study were male sex, older age, overweight or obesity, large neck circumference, abdominal obesity, snoring, hypertension, diabetes, alcohol consumption, and smoking. In the multivariable analysis, only older age, male sex, neck circumference, abdominal obesity, overweight or obesity, and snoring remained independently associated with SDB. Our data

also showed an association between SDB and living in urban areas, as already reported in China.²⁷ However, this association was probably caused by differences in anthropometric characteristics, such as the higher obesity rate in the urban population, because it was no longer statistically significant in the adjusted models. Nevertheless, the higher prevalence of SDB in urban versus rural settings could help to identify target populations for public health actions.

Several studies have shown a direct association between SDB severity and hypertension.^{28–30} In our study, there was a positive and independent association between SDB and hypertension with a linear trend across SDB severity categories in women, but not in men. This is consistent with findings in Switzerland where a study done in the HypnoLaus cohort also found this association exclusively in women.³¹ This finding could suggest that SDB treatment could have a greater effect on hypertension in women than men, but further studies are needed to confirm this assumption and investigate the underlying cause of this sex difference.

The main strengths of our study include the fact that it was done in a large sample that relied on both rural and urban participants in Benin. Moreover, SDB was assessed using objective sleep measures. However, there are some

limitations that should be mentioned. First, the sample, although large and from several geographic settings, represents random individuals that agreed to participate and might not represent the population in Benin. Second, female participants were disproportionately represented in our sample because they were more available to participate to the study during the survey visits. Therefore, to account for this recruitment difference, SDB prevalence data were reported by sex. Third, because of the acceptance and availability of study subjects and temporary COVID-19 restrictions, only about 60% of BeSAS study participants could undergo respiratory polygraphy according to preset quality criteria. However, there were no important differences between participants who underwent polygraphy and those who did not. Fourth, we used polygraphy to record sleep respiratory events, while the gold standard is polysomnography. Although polygraphy has been validated for SDB diagnosis,³² its use might have underestimated true SDB prevalence because arousals could not be considered to score hypopnoeas, and AHI was calculated based on estimated sleep time instead of measured total sleep time. Fifth, among SDB-associated comorbidities, only hypertension and diabetes could be assessed in this study, whereas several other conditions, such as mood disorders, metabolic syndrome, cognitive decline, and cardiovascular diseases, could also be associated with SDB. Lastly, although night and day duration and temperature variations were mild over the year in Benin (close to the equator line), we acknowledge that no adjustment was made in our results regarding the time of the year.

Despite these limitations, we believe that, by providing the first objectively measured data on SDB in a large national cohort from Africa, the BeSAS study fills a major gap in the sleep apnoea epidemiology literature and paves the way for further research on the African continent. Furthermore, our data could help to refine the worldwide modelised estimates of SDB prevalence by Benjafield and colleagues,⁹ who did not include any objective data from Africa in their model. As a result, their estimated prevalence of moderate-to-severe SDB in Benin for example was 22·9%,⁹ whereas we found a prevalence that was two-times lower (11·6%) in our study. Although this difference may be caused, in part, by a possible underestimation of the prevalence by the polygraphic (instead of polysomnography) recordings, it strengthens the need for more data in the African continent.

In conclusion, we showed that more than one in three women and one in two men were affected by mild-to-severe SDB in Benin, a prevalence that was high but similar to that reported on other continents. Advanced age, male sex, large neck circumference, abdominal obesity, overweight or obesity and snoring were factors independently associated with SDB in our population. In addition, we found an independent association between hypertension and SDB exclusively in women. The high SDB prevalence documented in this study should

stimulate the development of public health policies to prevent and treat SDB in Benin and other African countries.

Contributors

AAF contributed to the investigation and data curation. APW to the conceptualisation, investigation, funding acquisition, project administration, writing of the original draft, and submission of the manuscript. CH to the conceptualisation and investigation. DH to the conceptualisation, investigation, and writing, review, and editing of the manuscript. FA to the investigation and project administration. GA to the investigation, data curation, validation, formal analysis, and writing of the original draft. GS and MB to the data curation and writing of the original draft. PL and P-MP to the data curation, and writing, review, and editing of the manuscript. PM-V to the data curation, and writing of the original draft. RH to the conceptualisation, validation, data curation, funding acquisition, and writing of the original draft. SeA and SaA to the conceptualisation and investigation. TT to the investigation, data curation, and formal analysis. All authors have full access to all the data and accept responsibility to submit for publication.

Declaration of interests

RH is member of the medical advisory board of Dream and Nightbalance (Philips) and received honorariums, grants, or speakers' fees from ResMed, Jazz, Inspire, Philips, and Dream. All the other authors declare no competing interests.

Data sharing statement

The data supporting the study findings can be shared upon direct request to the corresponding author in a collaborative research approach. Please find hereafter the names of the authors who verified the data and who have full access to the raw data: APW, TT, AAF, GS, and RH.

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