The prevalence of sleep-disordered breathing in Northwest Russia: The ARKHsleep study

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Abstract

Sleep-disordered breathing (SDB) is a chronic condition characterized by repeated breathing pauses during sleep. The reported prevalence of SDB in the general population has increased over time. Furthermore, in the literature, a distinction is made between SDB, obstructive sleep apnea (OSA), and "OSA syndrome" (OSAS). Patients with SDB are at increased risk of comorbid cardiovascular diseases (CVDs). The aim of the ARKHsleep study was to assess the prevalence of SDB in general and of OSA and OSAS in particular. A total of 1050 participants aged 30–70 years, who were randomly selected from a population register, were evaluated for the probability of SDB using the Epworth Sleepiness Scale score and body mass index. Sleep was recorded for one night via home sleep apnea testing (Somnolter®). Medical conditions were determined from medical records. Additional data included background characteristics, anthropometric variables, blood pressure, and scores from four questionnaires. The survey sample consisted of 41.2% males and had a mean age of 53.1 ± 11.3 years. The prevalence of mild-to-severe, moderate-to-severe, and severe SDB was 48.9% [45.8–51.9], 18.1% [15.9–20.6], and 4.5% [3.2–5.8], respectively. Individuals reporting snoring or breathing pauses had a higher severity of SDB than individuals free of symptoms. The ARKHsleep study revealed a high burden of both SDB and CVD; however, more large-scale cohort studies and intervention studies are needed to better understand whether the early recognition and treatment of mild SDB with or without symptoms will improve cardiovascular prognosis and/or quality of life.

Introduction

Sleep-disordered breathing (SDB) is a chronic condition characterized by repeated breathing pauses during sleep.[1] Periods of breathing pauses may result in arousal, sleep fragmentation, increased activation of the sympathetic nervous system, and fluctuation in blood pressure (BP).[2] People with SDB may complain of snoring, tiredness, morning headaches, insomnia, or difficulty initiating sleep, but SDB can be asymptomatic.[3] Furthermore, patients with SDB are at increased risk of comorbid cardiovascular pathology and adverse cardiovascular events.[4–7]

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The main criterion for diagnosing SDB is the apnea–hypopnea index (AHI), which is defined as the number of apneas and/or hypopneas per hour of sleep measured during a sleep study.[8] While laboratory-based attended polysomnography (PSG) remains the "gold-standard" for the diagnosis of SDB, the American Academy of Sleep Medicine (AASM) suggested that home sleep apnea testing (HSAT) can be an acceptable alternative if the monitoring comprises the following: oronasal thermal airflow sensor, respiratory inductance plethysmography (RIP) and pulse oximetry.[8] Screening questionnaires can be used to stratify patients based on their clinical symptoms, physical examinations, and risk factors to identify those at high risk and in urgent need of sleep study and/or further treatment.[9]

SDB is an umbrella term used to combine sleep-related breathing disorders and other abnormalities of respiration during sleep. According to the AASM style guide for Sleep Medicine Terminology (November 2015)[10] and the International Classification of Sleep Disorders–Third Edition (ICSD-3, 2014),[11] SDB includes the following types: OSA disorders, central sleep apnea syndromes, sleep-related hypoventilation disorders, and sleep-related hypoxemia disorder. Obstructive sleep apnea (OSA) is considered to be the most frequent type of SDB[6,12,13] and is characterized by repeated episodes of partial or complete upper-airway collapse during sleep.[1] Moreover, in the literature, a distinction is made between OSA and OSA syndrome (OSAS). According to the AASM and ICSD-3,[11] OSAS is identified in cases in which an AHI ≥ 5 on PSG or HSAT is combined with one of the following symptoms: complaints of sleepiness, nonrestorative sleep, fatigue, or insomnia symptoms; the presence of breathing pauses, gasping, or choking detected by patient or his or her bed partner; or the presence of diagnosed hypertension, a mood disorder, cognitive dysfunction, coronary artery disease, stroke, congestive heart failure, atrial fibrillation, or type 2 diabetes mellitus. However, OSA is diagnosed if PSG or HSAT demonstrates ≥ 15 obstructive apneas and/or hypopneas per hour of sleep even in the absence of associated symptoms. In a recent study,[14] it was observed that symptom-positive patients have higher odds of SDB than symptom-negative persons but that the severity of SDB in those who answered "do not know" about breathing pauses was even higher than the severity in those who denied this symptom.

The Russian population is unique among Caucasian populations because of the very high prevalence of cardiovascular diseases (CVDs) and the marked sex gap in life expectancy. According to the Russian Federal State Statistics Service,[15] in 2018, the incidence rate of CVD was 32.1 per 1000 people. Cardiovascular pathology remains the leading cause of death in the Russian Federation. Furthermore, the Russian population has a high prevalence of CVD risk factors, including smoking, obesity, diabetes, and hypertension.[16] Thus, this population can be at a particularly higher risk for SDB. In the Russian Federation, as in the rest of the world,[17,18] SDB is underdiagnosed. No studies are available on the prevalence of the various clinical types of SDB in a general unselected population with investigations into the potential associations with age, sex, other clinical conditions, and lifestyle.

We designed the ARKHsleep study to assess the prevalence of SDB in general and OSA and OSAS, in particular, using portable HSAT equipment and updated definitions in the adult population of Arkhangelsk and to investigate their risk factors and associations with cardiovascular and metabolic comorbidities.

Methods

The ARKHsleep study is a collaboration between the Université Catholique de Louvain (Belgium) and the Northern State Medical University in Arkhangelsk (Russian Federation). The study protocols were approved by the ethics board of the Northern State Medical University (protocol N 01/11-14 from 27.11.2014).

The ARKHsleep study includes two components: a cross-sectional study (prevalence and diagnostic) and a cohort study. In the present article, we focused on the cross-sectional data.

Details concerning the design of the study, the sample size calculation, and the assessment of the participants can be found in Supplemental Appendix 1. We summarize here some key features of our study.

Participants

The study population was randomly selected from the lists of the Arkhangelsk Municipal Clinical Polyclinic No. 2 (these patient lists are organized based on territories), which provides medical care for over 38,000 people between the ages of 30–70 years and covers 20% of the city population of that age.

For logistical reasons, to avoid too many negative results, we decided to examine patients with a high pretest risk of SDB and a control group form by which extrapolation prevalence estimates could be made.
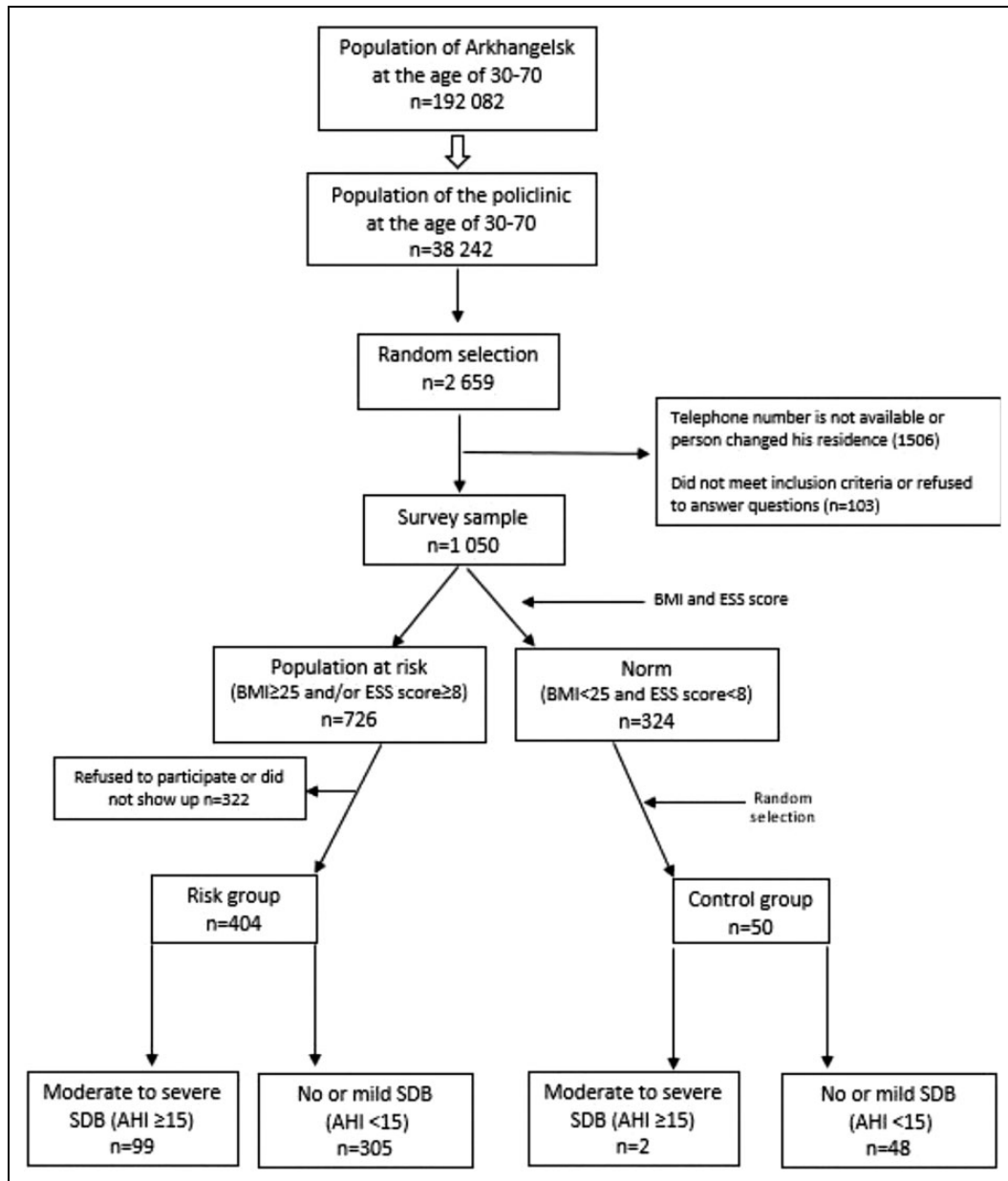
Figure 1. Flowchart of the ARKHsleep study. AHI: apnea/hypopnea index; ESS: Epworth Sleepiness Scale; SDB: sleep-disordered breathing.

The flowchart of the ARKHsleep study is shown in Figure 1.

First, we randomly selected 2659 patients aged 30–70 years as potential participants in the study using a random number generator. All selected subjects were interviewed by telephone using the Epworth Sleepiness Scale (ESS)[19] to assess the severity of daytime sleepiness and were asked about their weight and height to calculate body mass index (BMI). We decided to use these inclusion criteria, while the other risk scores require some physical examination and data from the medical records.

Background characteristics

Background characteristics included variables, such as sex, age, and socioeconomic status, and were collected via self-reported questionnaires. Smoking status was ascertained by asking whether the patient was a current, former (quit smoking over 6 months ago), or never smoker. Former and current smokers were asked

about how many years they had smoked and how many cigarettes per day they had smoked (in pack-years). One pack-year of smoking indicated that an individual smoked one package of cigarettes (20 cigarettes) daily for 1 year.

Questionnaires

The Pittsburgh sleep quality index (PSQI) was used to assess sleep quality.[20] The snoring, tiredness, observed apnea, high BP-BMI, age, neck circumference and gender (STOP-Bang)[21] questionnaire, and the Berlin questionnaire[22] were used to investigate their diagnostic characteristics in our test population.

Clinical evaluation

A comprehensive examination included standard BP measurement and anthropometric variables. Information regarding history of type 2 diabetes mellites, congestive heart failure, atrial fibrillation, arterial hypertension, dysrhythmias, stroke or transient ischemic attack, myocardial infarction, and medical treatment was obtained from a self-report questionnaire and medical records and was approved by the attending doctor.

Sleep study

To define the presence of SDB, we used the Somnolter® ambulatory monitor (Nomics, Belgium), which is a portable home-monitoring device used to assess the presence of different clinical types of sleep-related breathing disorders via the measurement of oxygen saturation, mandibular movements, body position, heart rate, nasal airflow, and thoracic and abdominal breathing movements.[23] The Somnolter® device has software that provides rapid and high-performance display and scoring with manual or automatic analysis. The automatic analysis detects all abnormal respiratory events: apneas, hypopneas, upper-airway resistance, and abnormal respiratory effort, as defined by the 2012 version of the AASM guidelines.[24] Several studies have shown that jaw movement analysis is a reliable method for distinguishing sleep-wake status and thus can be used as an alternative to actigraphy.[25–27] The device can recognize the nature of SDB: central or obstructive. Supplemental Appendix 2 presents the Somnolter® device appearance and a screenshot of recorded signals. A detailed description of how the sleep studies were performed can be discovered in Supplemental Appendix 3. In our study, we focused on two AHI cut-offs: AHI $\geq$ 5 (mild-to-severe SDB) and AHI $\geq$ 15 (moderate-to-severe SDB).

Sensitivity analysis

To investigate potential selection bias and the robustness or our prevalence estimations, we explored the impact of possible nonrandomness of nonparticipation in the study. In our study, we had information about sex, age, BMI, sleepiness, and smoking in persons in the risk group who refused to participate in the study. We assumed that the nonparticipants were missing at random. The sensitivity analysis was based on two simulations: (1) The prevalence of moderate-to-severe SDB (AHI $\geq$ 15) in the nonparticipants was 15% and (2) the prevalence of moderate-to-severe SDB (AHI $\geq$ 15) in the nonparticipants was 30%.

Statistical analysis

All data were stored in a central database. SPSS version 23.0 (SPSS Inc., Chicago, Illinois, USA) was used for data analysis. Descriptive statistics were calculated for all variables with the continuous variables presented as the mean $\pm$ standard deviation and the categorical variables presented as numbers and frequencies. The baseline variables were compared across groups with one-way analysis of variance, and Pearson's χ^2 test was carried out for the categorical variables. Statistical significance was set at <0.05 (a two-tailed probability value).

To determine a confidence interval for our sample proportion, estimating the proportion of the whole population of the policlinic and to check the reliability of this estimation, we used the following formula: $ci = p \pm Z_{\alpha/2}\sqrt{\left(\frac{1}{n}\right)p(1-p)\text{FPC}}$. In this formula, FPC refers to finite population correction and is equal to $(N-n)/(N-1)$, $Z_{\alpha/2}$ is the critical value of the normal distribution at $\alpha/2$ (e.g. for a confidence level of 95%, α is 0.05, and the critical value is 1.96), p is the sample proportion, n is the sample size, and N is the population size.[28]

To examine the association of moderate-to-severe SDB with risk factors, we performed multivariable analysis. The dependent variable was AHI $\geq$15. All significant associations that were found in the univariate analysis were entered as covariates. To determine the confounding effect of individual covariates, we added each covariate individually into a logistic regression.

Results

Sample characteristics

Initially, participants aged 30–70 years from the patient list of the polyclinic were selected using a random number generator; in total, 1050 individuals met the inclusion criteria and agreed to answer questions. Of these, 726 were in the group with a high risk of SDB (had BMI over 25 and/or ESS score over or equal to 8) and 324 had a low risk of SDB (normal BMI and ESS score less than 8). A total of 322 participants in the high-risk group declined to participate or did not participate in the examination and were excluded. We found no differences between the excluded and included subjects, concerning age, sex, BMI, smoking, or ESS score. The flowchart of the ARKHsleep study is shown in Figure 1.

The survey sample consisted of 41.2% males and had a mean age of 53.1 ± 11.3 years because of oversampling the 30–70 age group. Table 1 presents the sociodemographic, anthropometric, and clinical characteristics of the study cohort. The mean BMI was abnormal for the whole cohort ($29.7 \pm 5.9\,\text{kg/m}^2$) because elevated BMI was one of the inclusion criteria. While an ESS score over 8 was one of the possible inclusion criteria for the risk group, we found that for the whole study sample, the mean ESS score was within the normal range, 6.7 ± 4.0 points. The ARKHsleep population included fewer current and exsmokers than the average Russian population[29,30] (46.0% vs. 55.2%, respectively, $p < 0.05$). The study population was characterized by a very high prevalence of comorbid cardiovascular pathology. Hypertension and heart failure were observed in approximately 64% and 8% of the cohort, respectively.

SDB prevalence

Overall, 24.5% of the risk group and 4% of the control group met the criteria for moderate-to-severe SDB (AHI ≥ 15). After extrapolation of these results to the overall ARKHsleep population, we ended up with a prevalence of 18.1% [15.9–20.6]. Because prior studies have used a wide range of SDB definitions according to different AHI thresholds, we calculated prevalence for different cutoff values. As a result, the prevalence of mild-to-severe SDB (AHI ≥ 5) was 48.9% [45.8–51.9], and severe SDB (AHI ≥ 30) was recorded in 4.5% [3.2–5.8] of the population aged 30–70 years. None of the participants reported previously diagnosed sleep apnea.

The results of the sensitivity analysis using two different scenarios showed no relevant difference

Table 1. Sociodemographic, anthropometric, and clinical characteristics of the study sample ($n = 454$).[a]

Mean age (years)	53.1 ± 11.3
Male sex, *n* (%)	187 (41.2)
Mean BMI (kg/m²)	29.7 ± 5.9
Neck circumference (cm)	37.4 ± 4.0
Waist-to-hip ratio	0.9 ± 0.1
Sagittal diameter (cm)	25.3 ± 4
Smoking	
Smokers/former smokers[b]	209 (46.0)
Marital status	
Married, *n* (%)	276 (60.8)
Single, *n* (%)	149 (32.8)
Not answered, *n* (%)	29 (6.4)
Education	
Elementary, *n* (%)	6 (1.8)
Secondary, *n* (%)	12 (2.6)
Advanced, *n* (%)	13 (2.9)
Incomplete higher, *n* (%)	213 (46.9)
Higher, *n* (%)	14 (3.1)
Not answered, *n* (%)	29 (6.4)
Working status	
Full-time, *n* (%)	250 (55.1)
Part-time, *n* (%)	28 (6.2)
Not working, *n* (%)	147 (32.4)
Not answered, *n* (%)	29 (6.4)
Mean AHI (n/h)	10.4 ± 12.2
Mean oxygen desaturation index (n/h)	10.8 ± 12.5
Arterial hypertension, *n* (%)	292 (64.3)
Mean systolic BP (mmHg)	131 ± 17
Mean diastolic BP (mmHg)	83 ± 11
Heart failure, *n* (%)	37 (8.1)
Atrial fibrillation, *n* (%)	16 (3.5)
Arrythmias, *n* (%)	30 (6.6)
Myocardial infarction, *n* (%)	19 (4.2)
Cerebrovascular accident/TIA, *n* (%)	15 (3.3)
Type 2 diabetes, *n* (%)	50 (11.0)
Questionnaires	
ESS mean score	7 ± 4
Score ≥ 10, *n* (%)	110 (24.2)
PSQI score	6 ± 3
BQ high risk, *n* (%)	138 (30.4)
STOP-Bang score ≥ 5, *n* (%)	118 (26.0)

AHI: apnea–hypopnea index; BMI: body mass index; BP: blood pressure; BQ: Berlin questionnaire; ESS: Epworth Sleepiness Scale; PSQI: Pittsburgh sleep quality index; TIA: transient ischemic attack; n/h: Number of events per hour.
[a]Variables are expressed as numbers (percentage) or mean with standard deviation for data that is normally distributed.
[b]Mean smoking status for smokers and former smokers was 18.9 in pack-years.

between the prevalence of moderate-to-severe SDB in the ARKHsleep population. In model 1, where the prevalence of moderate-to-severe SDB in

Table 2. Anthropometric and clinical characteristics of the participants by severity of sleep-disordered breathing.[a]
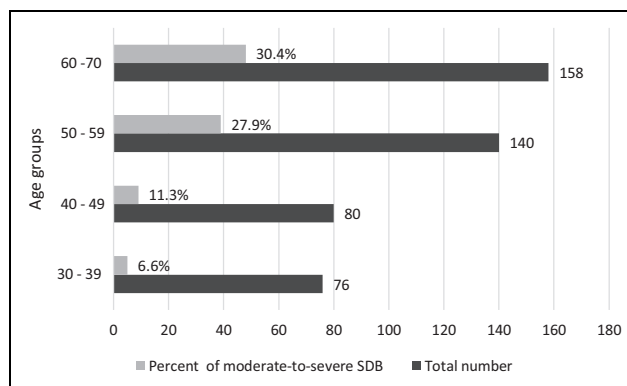
	No or mild SDB (n = 353)	Moderate-to-severe SDB (n = 101)	p Value
Mean age (years)	51.8 ± 11.6	57.8 ± 8.8	0.002
Age 30–49 years, n (%)	142 (40.2)	11 (13.9)	0.000
Age 50–70 years, n (%)	211 (59.8)	87 (86.1)	
Male sex, n (%)	148 (41.9)	39 (38.6)	0.6
Mean BMI (kg/m^2)	28.5 ± 5.4	33.8 ± 6.0	0.000
Neck circumference (cm)	36.9 ± 3.9	39.4 ± 3.9	0.000
Waist-to-hip ratio	0.89 ± 0.1	0.96 ± 0.1	0.000
Smoking, mean pack-years	8.1 ± 14.6	10.0 ± 16.2	0.3
Mean AHI	5.6 ± 4.2	27.3 ± 15.6	0.000
Mean oxygen desaturation index (n/h)	6.0 ± 5.2	27.3 ± 15.9	0.000
Arterial hypertension, n (%)	205 (58.6)	87 (86.1)	0.000
Mean systolic BP (mmHg)	129 ± 17	136 ± 15	0.000
Mean diastolic BP (mmHg)	83 ± 10	86 ± 10	0.006
Heart failure, n (%)	24 (6.9)	13 (12.9)	0.046
Atrial fibrillation, n (%)	10 (2.9)	6 (5.9)	0.2
Arrythmias, n (%)	23 (6.6)	7 (6.9)	0.4
Myocardial infarction, n (%)	12 (3.4)	7 (6.9)	0.3
Cerebrovascular accident/TIA, n (%)	11 (3.1)	4 (3.9)	0.6
Type 2 diabetes, n (%)	31 (8.9)	19 (19.2)	0.004
Questionnaires			
ESS score ≥ 10, n (%)	87 (24.6)	23 (22.8)	0.8
PSQI score	6 ± 3	7 ± 3	0.2
BQ high risk, n (%)	87 (47.8)	51 (83.6)	0.000
STOP-Bang score ≥ 5, n (%)	71 (20.1)	47 (46.5)	0.000

AHI: apnea–hypopnea index; BMI: body mass index; BP: blood pressure; BQ: Berlin questionnaire; ESS: Epworth Sleepiness Scale; PSQI: Pittsburgh sleep quality index; SDB: sleep-disordered breathing; TIA: transient ischemic attack; n/h: Number of events per hour.
[a]No or mild sleep-disordered breathing was defined as an AHI less than 15 events per hour. Moderate-to-severe sleep-disordered breathing was defined as an AHI ≥15 events per hour. Variables are expressed as numbers (percentages) or the mean with standard deviation for data that are normally distributed. Significant differences ($p < 0.05$) within the sex group (p value for Pearson's χ^2 test).

nonparticipants was 30%, we determined a 19.8% [17.5–22.3] prevalence in the total survey sample. In model 2, with a 15% prevalence of moderate-to-severe SDB in nonparticipants, we end up with a 15.1% [13.3–17.4] prevalence among the total survey sample.

A comparison of the anthropometric and clinical characteristics of the participants by the severity of SDB is presented in Table 2. We found no sex differences between the SDB severity groups. However, subjects with moderate-to-severe SDB were significantly older, more obese, and had higher neck circumference than those with AHI <15. Additionally, we found that the proportion of moderate-to-severe SDB significantly increased with age (p for χ^2 statistics 0.000) (Figure 2). In univariate analysis, subjects with moderate-to-severe SDB had a higher prevalence of CVD and metabolic diseases (arterial hypertension, heart failure, and type 2 diabetes) than subjects with

Figure 2. Prevalence of moderate-to-severe SDB (AHI ≥ 15) by age group. AHI: apnea/hypopnea index; SDB: sleep-disordered breathing.

no or mild SDB. As given in Table 3, multivariable adjustment revealed an association between moderate-to-severe SDB (AHI cutoff over 15) and age and BMI. However, we found that the association

Table 3. Logistic regression for the association of age and moderate-to-severe SDB (AHI $\geq$ 15).[a]

	Crude	Model 1	Model 2
Age	1.06 [1.03–1.08][b]	1.03 [1.01–1.06][b]	1.03 [1.00–1.06][b]
Arterial hypertension		2.09 [1.47–5.73][b]	1.09 [0.93–3.92]
Heart failure		1.17 [0.56–2.44]	1.07 [0.49–2.35]
BMI			1.13 [1.09–1.18][b]
Type 2 diabetes			1.16 [0.59–2.32]

AHI: apnea–hypopnea index; BMI: body mass index; SDB: sleep-disordered breathing.
[a]Model 1 included the following covariates: age, arterial hypertension and heart failure. Model 2 included the covariates of Model 1 plus BMI and type 2 diabetes.
[b]Significant association ($p \leq 0.05$).

Table 4. Sleep patterns of the population by severity of sleep-disordered breathing.[a]

	Total sample ($n = 454$)	No or mild-to-moderate SDB ($n = 353$)	Moderate-to-severe SDB ($n = 101$)
Apnea–hypopnea index (n/h)	10.4 $\pm$ 12.2	5.6 $\pm$ 4.2	27.3 $\pm$ 15.6
Respiratory disturbance index (n/h)	24.8 $\pm$ 15.0	19.3 $\pm$ 9.5	43.9 $\pm$ 15.5
Respiratory effort (%)	33.4 $\pm$ 19.4	29.7 $\pm$ 19.1	46.2 $\pm$ 14.4
Oxygen desaturation index (n/h)	10.8 $\pm$ 12.5	6.0 $\pm$ 5.2	27.4 $\pm$ 15.9
Obstructive apnea index (n/h)	3.1 $\pm$ 7.3	1.2 $\pm$ 1.6	10.1 $\pm$ 12.9
Obstructive hypopnea index (n/h)	5.9 $\pm$ 6.8	3.5 $\pm$ 3.1	14.4 $\pm$ 8.9
Central apnea index (n/h)	0.5 $\pm$ 0.9	0.5 $\pm$ 0.9	0.8 $\pm$ 1.2
Mixed apnea index (n/h)	0.8 $\pm$ 2.0	0.5 $\pm$ 1.4	2.0 $\pm$ 3.2
Hypopnea without desaturation (n/h)	9.2 $\pm$ 5.1	8.7 $\pm$ 4.6	11.0 $\pm$ 6.2
RERA (n/h)	5.2 $\pm$ 4.2	5.0 $\pm$ 4.3	5.9 $\pm$ 4.1

AHI: apnea–hypopnea index; RERA: respiratory effort-related arousal; SDB: sleep-disordered breathing; n/h: Number of events per hour.
[a]No or mild-to-moderate sleep-disordered breathing was defined as an AHI less than 15 events per hour. Moderate-to-severe sleep-disordered breathing was defined as an AHI $\geq$ 15 events per hour. Variables are expressed as the mean with standard deviation for data that are normally distributed.

of SDB with arterial hypertension adjusted for age was reduced after adjusting for BMI.

Sleep patterns

A comparison of sleep data between participants with and without moderate-to-severe SDB is presented in Table 4. The mean AHI was 10.4 $\pm$ 12.2 in the whole survey sample and varied widely, as expected, among severity groups (5.6 $\pm$ 4.2 for no/mild-to-moderate and 43.9 $\pm$ 15.56 for moderate-to-severe).

Among respiratory events, most were obstructive apneas or hypopneas. We found a small number of central apneas (the mean central apnea index < 1) in both severity groups. Mixed apneas (with mean mixed apnea index > 5) were present in only subjects with moderate-to-severe SDB.

Sleep symptoms and SDB severity

The four SDB severity groups were assessed regarding sleep-related signs and symptoms (see Table 5). A

significant difference between groups was found for only snoring and breathing pauses ($p \leq 0.001$). Individuals reporting snoring or breathing pauses had a higher severity of SDB than individuals free of these symptoms. Moreover, it should be noted that many participants with no SDB (AHI < 5) reported snoring and breathing pauses (44.8% and 12.9%, respectively). Daytime fatigue did not differ between the SDB severity groups. Additionally, no differences were found in subjective sleepiness, as assessed by an ESS score $\geq$10 between SDB severity groups. The predictive values of SDB signs and symptoms are presented in Table 6. The positive predictive value (PPV) for the diagnosis of SDB was low, while the negative predictive value (NPV) was rather high for all SDB symptoms separately.

Discussion

This first population-based study in Russia provides new information on the prevalence of objectively

Table 5. The prevalence of symptoms in the total sample ($n = 545$), by severity of sleep-disordered breathing.

	No SDB AHI < 5 ($n = 195$)	Mild SDB AHI 5–14.9 ($n = 158$)	Moderate SDB AHI 15–29.9 ($n = 78$)	Severe SDB AHI ≥ 30 ($n = 23$)	p Value[a]
Snoring, n (%)	87 (44.8)	94 (59.5)	64 (82.1)	23 (100)	0.000
Breathing pauses, n (%)	25 (12.9)	25 (15.8)	20 (25.6)	17 (73.9)	0.000
Fatigue, n (%)	87 (44.8)	60 (37.9)	29 (37.2)	14 (60.9)	0.9
Sleepiness ESS ≥ 10, n (%)	48 (24.6)	39 (24.7)	16 (20.5)	7 (30.4)	0.9

AHI: apnea–hypopnea index; ESS: Epworth Sleepiness Scale; SDB: sleep-disordered breathing.
[a]p Value based on one-way analysis of variance. The symptoms were taken from the Berlin questionnaire and STOP-Bang score. If, in at least one questionnaire, a symptom was noted, then it was considered as positive.

Table 6. Predictive value of SDB symptoms for moderate-to-severe SDB estimated for the random control group sample ($n = 704$).[a]

	AHI ≥ 15 ($n = 111$)	AHI < 15 ($n = 593$)
Snoring		
Snoring ($n = 368$)	92	276
No snoring ($n = 336$)	19	317
Sensitivity (95% CI), %	82.9 [74.6–89.3]	
Specificity (95% CI), %	53.5 [49.3–57.5]	
PPV (95% CI), %	25.0 [22.8–27.3]	
Negative predictive value (95% CI), %	94.3 [91.7–96.2]	
Breathing pauses		
Breathing pauses ($n = 132$)	42	90
No breathing pauses ($n = 572$)	69	503
Sensitivity (95% CI), %	37.8 [28.8–47.5]	
Specificity (95% CI), %	84.8 [81.7–87.6]	
PPV (95% CI), %	31.8 [25.6–38.8]	
Negative predictive value (95% CI), %	87.9 [86.3–89.4]	
Fatigue		
Fatigue ($n = 245$)	43	202
No fatigue ($n = 459$)	68	391
Sensitivity (95% CI), %	38.7 [29.6–48.5]	
Specificity (95% CI), %	65.9 [61.9–69.7]	
PPV (95% CI), %	17.6 [14.1–21.6]	
Negative predictive value (95% CI), %	85.2 [83.1–87.1]	
Sleepiness, ESS ≥ 10		
Sleepiness ($n = 116$)	25	38,910
No sleepiness ($n = 588$)	86	502
Sensitivity (95% CI), %	22.5 [15.1–31.4]	
Specificity (95% CI), %	84.7 [81.5–87.5]	
PPV (95% CI), %	21.6 [15.6–28.9]	
Negative predictive value (95% CI), %	85.4 [84.0–86.6]	

CI: confidence interval; AHI: apnea–hypopnea index; ESS: Epworth Sleepiness Scale; PPV: positive predictive value; SDB: sleep-disordered breathing.
[a]Symptom was scored as positive if was mentioned in at least one of questionnaires.

measured SDB, SDB symptoms, and associated risk factors. Our study shows that SDB and SDB symptoms are highly prevalent in our population and highlights also that this problem is underestimated in Russia. None of the participants had been previously diagnosed with SDB, even in the presence of severe symptoms. The severity of SDB increased with age, and no sex differences were found. The distribution of sleep symptoms varied across severity categories of SDB, and symptoms were also highly prevalent even

in patients with no SDB. A statistically significant difference across severity groups was found for only objective symptoms: snoring and breathing pauses. Moderate-to-severe SDB was associated with an increased prevalence of arterial hypertension, heart failure, and type 2 diabetes.

In the latest studies, the prevalence of minimal SDB (cutoff point AHI > 5) in the general population has ranged between 25.8% and 83.8%.[14,31,32] Such variability can be partly explained by the changes in measurement techniques and scoring criteria for SDB over the past 30 years. Our findings are comparable to recent prevalence rates found using objective procedures similar to those used in our study.[33] Using recent definitions of SDB,[8] we estimated that approximately 49% of the population had minimal SDB, 18% had moderate or more severe SDB, and 4.5% had severe SDB. This difference may be explained by the age range (in some studies the age range was wider, 20–80[34] or 40–85[31] years versus 30–70 years in our study), genetic/ethnic factors (only white people in our study). We did not find any statistically significant difference in SDB prevalence between men and women. This is similar to what has been observed in some studies for the age group 50–60 years,[34,35] and the mean age of our survey sample was 53.1 ± 11.3 years.

Snoring and "stopping breathing" are SDB symptoms that are frequently used in clinical settings to predict SDB.[14] In contrast, no significant relationship was previously found between SDB and subjective symptoms, such as daytime sleepiness or fatigue.[3,36] The association between these symptoms and SDB in the ARKHsleep population is similar to what was found in prior studies, supporting the idea that the absence of symptoms allows us to exclude patients at high risk of SDB. Moreover, the low PPV jeopardizes the idea that only patients with suggested symptoms should be screened for possible SDB and for OSA, in particular. Additionally, a simple AHI cutoff of 15 may, therefore, be inadequate to define who needs to be treated. Moreover, based on the AASM and ICSD-3,[11] the distinction between OSA and OSAS is still made in clinical practice, and a physician's diagnosis should be based on both sleep data (PSG or HSAT) and patient complaints. In our opinion, supplementary interventional studies are required to understand whether treating asymptomatic SDB patients (and patients past which cutoffs) will improve cardiovascular prognosis.

None of the study participants reported sleep apnea previously diagnosed by a physician. Such a contradiction between a high prevalence of SDB and a low prevalence of diagnosed sleep apnea suggests that a large burden of SDB may be undiagnosed and untreated in the Russian population. The association of SDB with cardiovascular pathology is well known. It was found that SDB is strongly associated with cardiovascular pathology.[37,38] The most likely causal pathway through which SDB causes CVD is thought to be intermittent hypoxia, endothelial dysfunction and inflammation, repetitive arousal from sleep, large intrathoracic pressure variations and increased sleeping blood pressure.[39-44] In ARKH sleep, we identified an association of SDB with arterial hypertension and heart failure. Additionally, more severe SDB was associated with a higher risk of CVD. However, the fact that age and BMI were found to be confounders for both diseases needs to be studied and discussed. The prevalence of cardiovascular pathology is very high in Russia; for example, the estimated prevalence of arterial hypertension and heart failure was found to be 40.8% and 7-10%, respectively.[16,25,45,46] We found a very low proportion of central apnoea among all respirator events in our survey sample (with an 8% prevalence of heart failure), although in heart failure patients experiencing SDB, central sleep apnoea is more common than OSA.[47-51]

Strengths and limitations

The strengths of this study include the use of a random sampling method and the use of a control group. We calculated the diagnostic characteristics of SDB symptoms in an unselected population. We used the 2017 AASM recommended criterion for apnea (requiring a 90% reduction in oronasal flow) and hypopnea scoring (≥30% reduction in oronasal flow associated with ≥3% oxygen desaturation). All patients were monitored at home with equipment that was compliant with AASM guidelines as an acceptable alternative for hospital-based PSG.

The ARKHsleep study also had some limitations. We were not able to use electrophysiology. We relied on the Jawac signal to estimate sleep-wake status and arousals.[25,26] Another limitation was that HSAT was performed only for one night, and night-to-night variability can also cause some misclassification.

Conclusion

The results of this large study provide evidence of a high prevalence of symptoms and objectively measured SDB in the Arkhangelsk population. The

prevalence of mild-to-severe (AHI $\geq$ 5), moderate-to-severe (AHI $\geq$ 15), and severe SDB (AHI $\geq$ 30) was 48.9% [45.8–51.9], 18.1% [15.9–20.6], and 4.5% [3.2–5.8], respectively. Among respiratory episodes, most were obstructive apneas or hypopneas. We found a very small number of central and mixed apneas. Individuals reporting snoring or breathing pauses had a higher severity of SDB than individuals free of these symptoms. Additionally, subjects with moderate-to-severe SDB had a statistically higher prevalence of CVD and metabolic diseases (arterial hypertension, heart failure, and type 2 diabetes) than subjects with no or mild SDB.

The Russian population has a high burden of both SDB and CVD; however, more large-scale cohort studies are needed to better understand whether the early recognition and treatment of mild symptom-positive or -negative SDB will improve cardiovascular prognosis and quality of life.

Author contributions

The study design for the present study was performed by J-MD and EA; data collection by AK and EA; statistical analysis by AK and J-MD; and manuscript writing by AK. Critical reading of the manuscript was done by AK, EA, and J-MD.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplemental material

Supplemental material for this article is available online.

References

1. Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. The report of an American academy of sleep medicine task force. *Sleep* 1999; 22(5): 667–689.

2. White DP. Sleep-related breathing disorder. 2. Pathophysiology of obstructive sleep apnoea. *Thorax* 1995; 50(7): 797–804.

3. Arnardottir ES, Bjornsdottir E, Olafsdottir KA, et al. Obstructive sleep apnoea in the general population: highly prevalent but minimal symptoms. *Eur Respir J* 2016; 47(1): 194–202.

4. Abumuamar AM, Dorian P, Newman D, et al. The prevalence of obstructive sleep apnea in patients with atrial fibrillation. *Clin Cardiol* 2018; 41(5): 601–607.

5. Gami AS, Olson EJ, Shen WK, et al. Obstructive sleep apnea and the risk of sudden cardiac death: a longitudinal study of 10,701 adults. *J Am Coll Cardiol* 2013; 62(7): 610–616.

6. Gessner V, Bitter T, Horstkotte D, et al. Impact of sleep-disordered breathing in patients with acute myocardial infarction: a retrospective analysis. *J Sleep Res* 2017; 26(5): 657–664.

7. Hla KM, Young T, Hagen EW, et al. Coronary heart disease incidence in sleep disordered breathing: the Wisconsin Sleep Cohort Study. *Sleep* 2015; 38(5): 677–684.

8. Berry RB, Brooks R, Gamaldo C, et al. AASM scoring manual updates for 2017 (version 2.4). *J Clin Sleep Med* 2017; 13(5): 665–666.

9. Abrishami A, Khajehdehi A, and Chung F. A systematic review of screening questionnaires for obstructive sleep apnea. *Can J Anaesth* 2010; 57(5): 423–438.

10. American Academy of Sleep Medicine. *AASM style guide for sleep medicine terminology*. Darien, IL: American Academy of Sleep Medicine, 2016, http://www.aasmnet.org/jcsm/resources/documents/style-guide-sleep-medicine-terms.pdf

11. Sateia MJ. International classification of sleep disorders-third edition: highlights and modifications. *Chest* 2014; 146(5): 1387–1394.

12. Tung P, Levitzky YS, Wang R, et al. Obstructive and central sleep apnea and the risk of incident atrial fibrillation in a community cohort of men and women. *J Am Heart Asso* 2017; 6(7): e004500.

13. Javaheri S, Blackwell T, Ancoli-Israel S, et al. Sleep-disordered breathing and incident heart failure

in older men. *Am J Respir Crit Care Med* 2016; 193(5): 561–568.

14. Redline S, Sotres-Alvarez D, Loredo J, et al. Sleep-disordered breathing in Hispanic/Latino individuals of diverse backgrounds. The Hispanic Community Health Study/Study of Latinos. *Am J Respir Crit Care Med* 2014; 189(3): 335–344.

15. Russian Federal State Statistics Service. http://www.gks.ru/

16. Mareev VY, Fomin IV, Ageev FT, et al. Russian heart failure society, Russian society of cardiology. Russian scientific medical society of internal medicine guidelines for heart failure: chronic (CHF) and acute decompensated (ADHF). Diagnosis, prevention and treatment [in Russian]. *Kardiologiia* 2018; 58(6): 1–164.

17. Kapur V, Strohl KP, Redline S, et al. Underdiagnosis of sleep apnea syndrome in U.S. communities. *Sleep Breath* 2002; 6(2): 49–54.

18. Punjabi NM. The epidemiology of adult obstructive sleep apnea. *Proc Am Thorac Soc* 2008; 5(2): 136–143.

19. Doneh B. Epworth Sleepiness Scale. *Occup Med (Oxford, England)* 2015; 65(6): 508.

20. Buysse DJ, Reynolds CF 3rd, Monk TH, et al. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psych Res* 1989; 28(2): 193–213.

21. Chung F, Abdullah HR, and Liao P. STOP-Bang questionnaire: a practical approach to screen for obstructive sleep apnea. *Chest* 2016; 149(3): 631–638.

22. Senaratna CV, Perret JL, Matheson MC, et al. Validity of the Berlin questionnaire in detecting obstructive sleep apnea: a systematic review and meta-analysis. *Sleep Med Rev* 2017; 36: 116–124.

23. Cattrysse F, Peeters M, Calaerts S, et al. Detection of sleep apnea by case-finding and home monitoring with Somnolter(®): a pilot study. *BMC Res Notes* 2014; 7: 616.

24. Grigg-Damberger MM. The AASM Scoring Manual four years later. *J Clin Sleep Med* 2012; 8(3): 323–332.

25. Chakar B, Senny F, Poirrier AL, et al. Validation of midsagittal jaw movements to measure sleep in healthy adults by comparison with actigraphy and polysomnography. *Sleep Sci (Sao Paulo, Brazil)*. 2017; 10(3): 122–127.

26. Martinot JB, Le-Dong NN, Cuthbert V, et al. Mandibular movements as accurate reporters of respiratory effort during sleep: validation against diaphragmatic electromyography. *Front Neurol* 2017; 8: 353.

27. Senny F, Maury G, Cambron L, et al. The sleep/wake state scoring from mandible movement signal. *Sleep Breath* 2012; 16(2): 535–542.

28. Metcalfe C. Biostatistics: a Foundation for Analysis in the Health Sciences. 7th edn. Wayne W. Daniel, Wiley, 1999. No. of. pages: xiv+755+appendices. Price: £28.95. ISBN 0-471-16386-4. *Stat Med* 2001; 20(2): 324–326.

29. Ahluwalia IB, Smith T, Arrazola RA, et al. Current tobacco smoking, quit attempts, and knowledge about smoking risks among persons aged ≥15 years - Global Adult Tobacco Survey, 28 countries, 2008-2016. *MMWR Morb Mortal Wkly Rep* 2018; 67(38): 1072–1076.

30. Andreeva E, Pokhaznikova M, Lebedev A, et al. The RESPECT study: RESearch on the PrEvalence and the diagnosis of COPD and its Tobacco-related etiology: a study protocol. *BMC Publ Heal* 2015; 15: 831.

31. Heinzer R, Vat S, Marques-Vidal P, et al. Prevalence of sleep-disordered breathing in the general population: the HypnoLaus study. *Lancet Respir Med* 2015; 3(4): 310–318.

32. Plywaczewski R, Bednarek M, Jonczak L, et al. Sleep-disordered breathing in a middle-aged and older Polish urban population. *J Sleep Res* 2008; 17(1): 73–81.

33. Senaratna CV, Perret JL, Lodge CJ, Lowe AJ, Campbell BE, Matheson MC, et al. Prevalence of obstructive sleep apnea in the general population: a systematic review. *Sleep Med Rev* 2017; 34: 70–81.

34. Tufik S, Santos-Silva R, Taddei JA, et al. Obstructive sleep apnea syndrome in the Sao Paulo Epidemiologic Sleep Study. *Sleep Med* 2010; 11(5): 441–446.

35. Lee SD, Kang Sh, Gawon Ju, et al. The prevalence of and risk factors for sleep-disordered breathing in an elderly Korean population. *Respiration* 2014; 87(5): 372–378.

36. Ye L, Pien GW, Ratcliffe SJ, et al. The different clinical faces of obstructive sleep apnoea: a cluster analysis. *Eur Respir J* 2014; 44: 1600–1607.

37. Khokhrina A, Andreeva E, and Degryse J-M. The association of sleep disordered breathing and cardiovascular pathology in an adult population: a systematic review. *Reviewed, Sleep Medicine Reviews, in press.* 2019.

38. Yancy CW, Jessup M, Bozkurt B, et al. 2017 ACC/AHA/HFSA focused update of the 2013 ACCF/AHA guideline for the management of heart failure: a report of the American college of cardiology/American heart association task force on clinical practice guidelines and the heart failure society of America. *J Card Fail* 2017; 23(8): 628–651.

39. Punjabi NM, Newman AB, Young TB, et al. Sleep-disordered breathing and cardiovascular disease:

an outcome-based definition of hypopneas. *Am J Respir Crit Care Med* 2008; 177(10): 1150–1155.

40. Somers VK, White DP, Amin R, et al. Sleep apnea and cardiovascular disease: an American Heart Association/ American College Of Cardiology Foundation Scientific Statement from the American Heart Association Council for High Blood Pressure Research Professional Education Committee, Council on Clinical Cardiology, Stroke Council, and Council On Cardiovascular Nursing. In collaboration with the National Heart, Lung, and Blood Institute National Center on Sleep Disorders Research (National Institutes of Health). *Circulation* 2008; 118(10): 1080–1111.

41. Duran-Cantolla J, Aizpuru F, Montserrat JM, et al. Continuous positive airway pressure as treatment for systemic hypertension in people with obstructive sleep apnoea: randomised controlled trial. *BMJ* 2010; 341: c5991.

42. Cheliout-Heraut F, Senny F, Djouadi F, et al. Obstructive sleep apnoea syndrome: comparison between polysomnography and portable sleep monitoring based on jaw recordings. *Neurophysiol Clin* 2011; 41(4): 191–198.

43. Young T, Palta M, Dempsey J, et al. The occurrence of sleep-disordered breathing among middle-aged adults. *N Engl J Med* 1993; 328(17): 1230–1235.

44. Shahar E, Whitney CW, Redline S, et al. Sleep-disordered breathing and cardiovascular disease: cross-sectional results of the Sleep Heart Health Study. *Am J Resp Crit Care Med* 2001; 163(1): 19–25.

45. Chazova IE. Experts ZYVobot. Clinical guidelines. Diagnosis and treatment of arterial hypertension. *Syst Hyper* 2019; 16(1): 6–31.

46. Grigg-Damberger MM. The AASM scoring manual: a critical appraisal. *Curr Opin Pulm Med* 2009; 15(6): 540–549.

47. Sano K, Watanabe E, Hayano J, et al. Central sleep apnoea and inflammation are independently associated with arrhythmia in patients with heart failure. *Eur J Heart Fail* 2013; 15(9): 1003–1010.

48. MacDonald M, Fang J, Pittman SD, et al. The current prevalence of sleep disordered breathing in congestive heart failure patients treated with beta-blockers. *J Clin Sleep Med* 2008; 4(1): 38–42.

49. Berry RB, Gamaldo CE, Harding SM, et al. AASM scoring manual version 2.2 updates: new chapters for scoring infant sleep staging and home sleep apnea testing. *J Clin Sleep Med* 2015; 11(11): 1253–1254.

50. Appleton S, Gill T, Taylor A, et al. Influence of gender on associations of obstructive sleep apnea symptoms with chronic conditions and quality of life. *Int J Environ Res Public Health* 2018; 15(5): 930.

51. Humphry RW, Cameron A, and Gunn GJ. A practical approach to calculate sample size for herd prevalence surveys. *Prev Vet Med* 2004; 65(3–4): 173–188.