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SLEEP BREATHING PHYSIOLOGY AND DISORDERS • REVIEW

# Worldwide prevalence and associated risk factors of obstructive sleep apnea: a meta-analysis and meta-regression

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## Abstract

**Purpose** This study aimed to identify the prevalence of obstructive sleep apnea (OSA) and associated risk factors globally.

**Methods** Six databases and registrations and three grey databases were explored for observational field research. Independently and impartially paired reviewers selected research, gathered data, and evaluated the methodological quality. Heterogeneity was investigated using subgroup analysis and meta-regression following the moderating variable in a meta-analysis of proportions with a random-effects model. The critical appraisal instrument developed by the Joanna Briggs Institute was used to evaluate the listed studies' methodology. The certainty of the evidence was evaluated using the GRADE tool.

**Results** A total of 8236 articles were collected during the database search, resulting in 99 articles included for qualitative synthesis, and 98 articles were included for the meta-analysis. The estimated combined prevalence of OSA was 54% [CI 95% = 46–62%; I2 = 100%]. Mean age, percentage of moderate-severe cases, and the sample's body mass index (BMI) did not affect the heterogeneity that was already present when meta-regressed ($p > 0.05$). Ninety-one studies were deemed to have a low risk of bias, while eight were deemed to have a moderate risk. For OSA prevalence outcomes, the GRADE criteria were considered very low.

**Conclusion** Approximately half of the people worldwide have OSA. High BMI, increasing age, and male gender are described as risk factors in the literature, but these covariates do not affect pre-existing heterogeneity.

**Keywords** Obstructive sleep apnea · Risk factors · Prevalence · Systematic review

## Introduction

Recurrent bouts of partial or complete blockage of the upper airway during sleep constitute obstructed sleep apnea (OSA). When a person sleeps, the pharyngeal region, a portion of the upper airway, may constrict or collapse [1, 2]. Etiologies includes neuromuscular, anatomical, mechanical, and chemical factors [3, 4] and can be classified as mild, moderate, or severe [5]. Polysomnography (PSG) is the reference standard for its diagnosis [6, 7].

Oxygen desaturation, excessive sleepiness, poor attention, sleep awakenings, fragmented sleep, exhaustion, and changes in blood pressure and heart rate can all be symptoms of OSA [1, 2]. These symptoms can affect the patient's quality of life and increase the risk of road traffic accidents and depression [3].

Age, gender, and obesity are all recognized risk factors for OSA [4–7]. In addition, this condition is also associated

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with cardiovascular diseases [8], such as hypertension, congestive heart failure, nocturnal arrhythmias, atrial fibrillation, stroke, and type 2 diabetes [9]. Given that OSA is a public health issue because of its high incidence and correlation with higher mortality and morbidity, it is important to understand these relationships [10]. In order to comprehend the effects of OSA on the population and to develop public interventions, greater knowledge is necessary.

A recent systematic review addressed the frequency of OSA in the general population [7]. However, the search strategy was conducted through March 2016. Furthermore, this review used only two databases and did not use grey literature. Thus, there is a need to develop an updated systematic review with a broader search strategy to provide a qualitative and quantitative synthesis of the subject. Therefore, this study aimed to systematically review the literature on OSA prevalence and its associated risk factors worldwide.

## Methods

### Protocol

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards were followed while reporting this systematic review [11].

### Eligibility criteria

This study used the PECOS strategy [12] in this analysis to specify the following criteria for choosing studies: global population, denoted by the symbol "P"; Obstructive sleep apnea exposure (E); Comparison (C): Since this is prevalence research, there is no comparison; Obstructive sleep apnea prevalence and risk factors comprise the outcomes (O); Cross-sectional studies comprise the study design (S).

This research sought to determine the prevalence of OSA in the global population. Thus, we included studies that evaluated the global population, performed PSG for the OSA diagnosis, and measured the apnea-hypopnea index (AHI). There were no exclusion criteria related to language, year of publication, gender, or ethnicity.

Studies were excluded based on the following criteria: (1) Studies that did not evaluate the prevalence of obstructive sleep apnea; (2) Studies that did not perform home or complete PSG for OSA diagnosis, such as studies assessing OSA only with questionnaires or exclusively based on clinical diagnosis without testing; (3) Studies that did not provide AHI; (4) Studies that reported the prevalence of central sleep apnea; (5) Hospital-based studies and studies assessing OSA prevalence among patients with resistant hypertension, chronic kidney disease, heart failure, and stroke/neurological disease since OSA prevalence is much higher in these groups than in the global population; (6) Reviews, letters, books, conference abstracts, case reports, case series, opinion articles, technical articles, and guidelines; (7) Studies for which the full text were not available, even after requesting full texts from the authors.

### Information sources and search strategies

The Medical Subject Headings (MeSH) and the Health Sciences Descriptors were used to choose the descriptors (DeCS). The search strategy used a word combination (Appendix 1), with the word combinations and search phrases modified in each database as deemed necessary. In the following electronic databases, Embase, Latin American and Caribbean Literature on Health Sciences (LILACS), LIVIVO, PubMed (including MEDLINE), Scopus, and Web of Science, we performed the search in May 2021 and updated it in April 2022. In order to find the grey literature, we also ran searches on Google Scholar, OpenGrey, and ProQuest Dissertation and Theses. In order to locate papers missed by the searches in the electronic databases, we manually searched the references of the chosen manuscripts. In order to find unpublished or potentially relevant studies, experts with recognized expertise in the field were contacted by e-mail. The articles were imported into a reference manager program (EndNote X7.0.1, Thomson Reuters) to remove duplicate studies.

### Study selection

Initially, for calibration, the reviewers considered the eligibility requirements and used them on a small sample of retrieved papers to gauge inter-examiner agreement. Two investigators (ABAD and FMG) independently carried out a methodical analysis of the study titles and abstracts after attaining an acceptable degree of agreement (the Kappa Coefficient of Agreement 0.70) (phase 1). Subsequently, phase 2 involved the two reviewers reading the entire manuscripts independently. In the event of a disagreement, a third author (AAM) was consulted. We used the Rayyan website (http://rayyan.qcri.org) to blind the reading of references and allow this to occur independently and discreetly in both phases.

### Data collection process and data listing

Two investigators (ABAD and FMG) independently collected the following information from the studies: author, year of publication and country, sample characteristics, OSA definition criteria, OSA prevalence, and associated risk factors.

### Risk of study bias

The methodological quality was evaluated using the Joanna Briggs Institute Critical Appraisal (JBI) tool for

cross-sectional studies [13]. Using criteria that the reviewers have qualified with responses like "yes", "no", "uncertain", or "not applicable", it was possible to pinpoint the causes of bias through this procedure. The percentage of affirmative responses to the evaluation instrument's questions was used to categorize each study. When up to 49% of responses were "yes", the risk of bias was considered high. When 50 to 69% of responses were "yes", moderate, and when more than 70% of responses were "yes", low [14]. The JBI tool's criteria were examined separately by two investigators (ABAD and FMG). The third and fourth investigators (AAM and KVMT) were consulted in case of disagreements. RevMan 5.4 software created the figures (Review Manager 5.4, The Cochrane Collaboration).

### Summarization measures

The primary outcome included the prevalence of OSA, which was reported using relative or absolute frequencies and their accompanying 95% confidence intervals (95% CI).

### Summary of the results

A meta-analysis of proportions with a random effect model was performed using the DerSimonian and Laird estimator to calculate the Tau-squared [15]. Using the Higgins inconsistency index ($I^2$) [16], heterogeneity was evaluated. The Freeman-Tukey double arcsine transformation method ensured the data followed an approximately normal [17] distribution. In order to estimate the weight of the studies included in the analysis, the effect size of each study was weighted using the inverse variance method, calculating the estimate based on the inverse proportion of the study variance [17]. Confidence intervals of 95% CI were considered and calculated using the Clopper-Pearson method. All analyses and graphics were made using the statistical software Rstudio version 1.2.1335 (Rstudio Inc, Boston, USA).

### Assessment of reporting bias

The evaluation of the existence of publication bias was performed using the Egger test. In order to assess the influence of studies with low statistical power and higher probability of type-2 error, we conducted a sensitivity analysis removing studies with insufficient sample size to ensure adequate statistical power. Thus, we used the estimates obtained by the global effect for sample calculation, considering an infinite population, a 5% margin of error, and a 95% confidence level. We considered the following variables for subgroup analyses to assess the effect of potential confounding and risk factors on heterogeneity in the analysis: age group; country of origin of the sample; degree of OSA included in the sample (mild, moderate, severe, or not reported); initial screening for eligible patients or PSG performed in the entire sample; and conceptualization used by the authors to define the outcome (OSA or syndrome). Meta-regressions with a random-effects model were also performed to assess the impact of study characteristics on the observed variance between the effect sizes of the studies included in the analysis, considering the following factors: mean sample age, percentage of cases diagnosed as moderate-severe, and mean BMI of the sample. We used a 5% level of significance.

### Assessment of the certainty of evidence

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) standards were used to determine the degree of certainty in the available cumulative evidence [18]. Publication bias, indirect evidence, consistency, and imprecision were assessed by two investigators (AAM and KVMT). Consensus settled disagreements and a third investigator (CMA) was consulted if needed. The online program GRADEpro (McMaster University) generated an evidence profile. The level of evidence was classified as "high", "moderate", "low", or "very low".

## Results

### Study selection

The search technique revealed 8236 studies from the six electronic databases and the grey literature (excluding duplicate studies). A total of 199 studies were included for full-text evaluation after phase 1, while 100 studies were eliminated after phase 2. Thus, 99 studies for the qualitative analysis and 98 for the quantitative analysis were included. Figure 1 provides a summary of the full selection procedure. Appendix 2 presents the exclusionary factors.

### Characteristics of the studies

All included studies were classified as cross-sectional. Fourteen studies were conducted in the USA [19–32], followed by nine in Brazil [4, 33–40]; eight in China [41–48] and Australia [49–56]; seven in India [57–63]; five in Turkey [64–68], Thailand [69–73], and Spain [74–78]; four in Korea [79–82]; three in Germany [83–85]; and two in Canada [86, 87], Slovakia [88, 89], Japan [90, 91], Belgium [92, 93], Iran [94, 95], Greece [96, 97], and Italy [98, 99]. The remaining 17 were conducted in Sweden [100], Lebanon [101], Mexico [102], Oman [6], Ireland [103], Vietnam [104], Poland [105], Norway [106], South Africa [107], Colombia [108], Malaysia [109], Saudi Arabia [110], Portugal [111], Ecuador [112], Egypt [113], Mongolia [114], and Bangladesh [115] (Fig. 2).

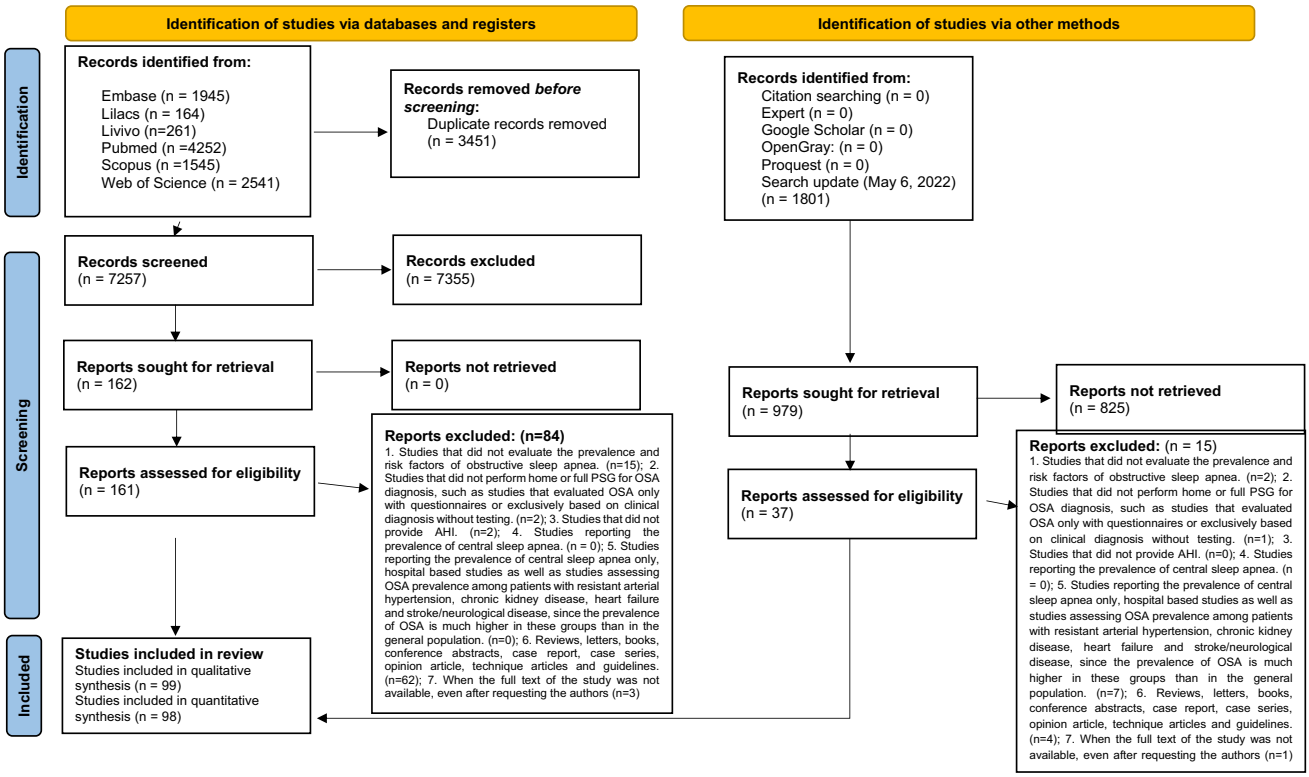


**Fig. 1** PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources

The sample size ranged from 22 [50] to 19371 [23] participants. All articles used PSG to identify OSA. However, 21 [23, 32, 57, 60–64, 66–68, 71, 84, 90, 91, 98, 104, 106, 110, 113, 115] used a screening questionnaire primarily aimed at directing high-risk patients to PSG, and two [75, 99] used either PSG or polygraphy. Table 1 provides the detailed characteristics of the included studies.

Estimates of prevalence for each subgroup reported in the 99 studies varied significantly. Table 2 shows the estimates for each subgroup. Adults and the elderly had the highest prevalence of OSA at 85%. When using PSG, the prevalence of OSA was 58%, and patients with mild to moderate OSA were the most prevalent when considering the classification of OSA. In terms of nationality, Mongolia and Taiwan (93%), Greece (82%), and Iran (81%) had the highest prevalence of OSA (Fig. 3).

## Risk of study bias

Regarding the overall risk of bias, eight studies [21, 69, 84, 90, 94, 104, 109, 113] were classified as having a moderate risk of bias, and 91 [4, 6, 19, 20, 22–68, 70–83, 85–89, 91–93, 95–103, 105–108, 110–112, 114, 115] were classified as having a low risk of bias. The lack of a thorough description of the study subjects and environments, the reliability of exposure assessment, and the absence of confounding factor control measures stood out as these studies' methodological flaws. Appendix 3 and Fig. 3 show the results of the risk of bias analysis.

## Results of the individual studies

The studies differed in the OSA prevalence, ranging from 12% [79] to 92% [37]. Sixty-one studies used the AHI > 5 to classify the presence of OSA, while the remaining studies used the AHI ranging from 1 to 30.

Among the risk factors for OSA, the most recurrent were body mass index (BMI) [21, 26–28, 32, 35, 38, 43, 45, 46, 50, 52, 55, 57, 61, 66, 67, 72, 80–82, 84, 93, 97, 98, 101, 102, 107, 109, 110, 114], cited by 31 articles, followed by age [26–28, 35, 38–40, 45, 52, 55, 60, 61, 71, 72, 81–83, 97, 100, 101, 107, 109–111, 115], cited by 25 articles; the male gender [24, 26, 27, 35, 47, 51, 52, 55, 60–62, 71, 72, 81–83, 92, 93, 101–104, 110, 115], cited by 24 articles; neck circumference [32, 35, 40, 43, 46, 48, 57, 66, 67, 72, 98, 102, 109, 113, 114], cited by 15 articles; obesity [39, 40, 47, 60, 61, 71, 87, 92, 105, 110, 111, 115], cited by 12; and hypertension [6, 26, 45, 52, 60, 71, 76, 77, 100, 109, 110], cited by 11 articles. In addition, some articles brought alcohol consumption [39, 71] and smoking [60, 71, 97] as risk factors.

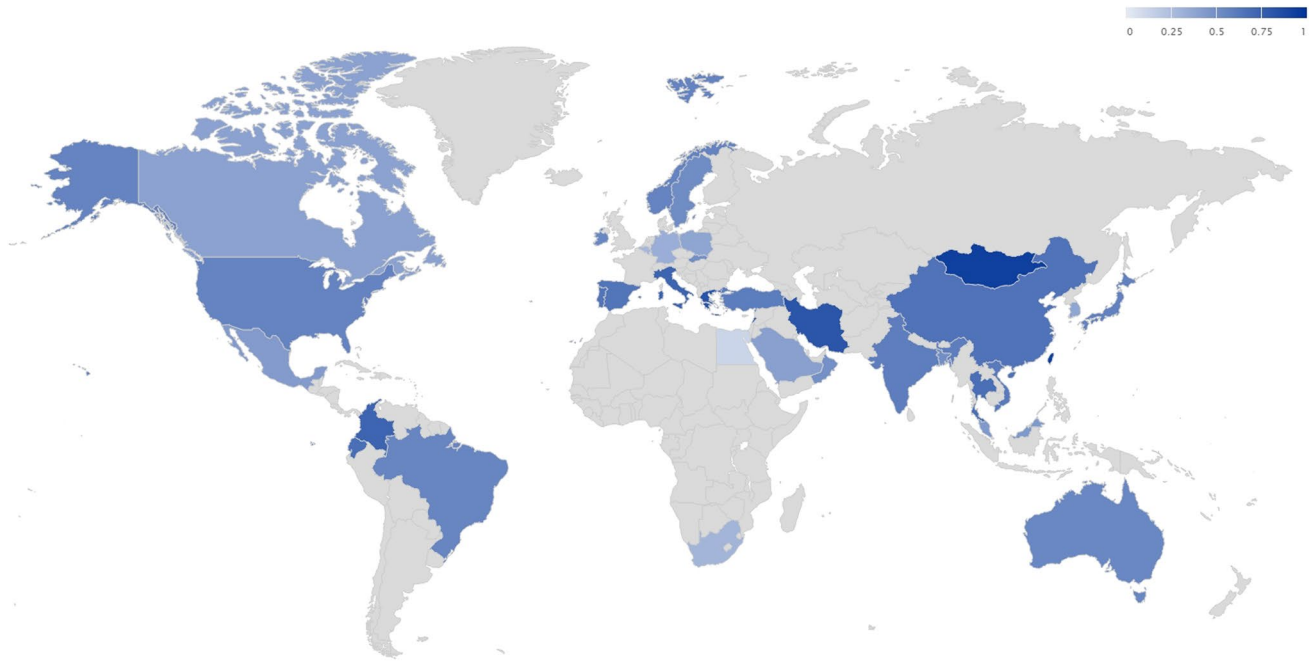


**Fig. 2** General heatmap of OSA prevalence and country where the studies were performed

### Summary of the results

The analysis included 47634 people, with the OSA prevalence estimated to be 56% [95% CI = 51–61%; $I^2 = 99\%$] (Fig. 3). We calculated the sample size using this obtained prevalence and considering an infinite population, a 5% margin of error, and a 95% confidence level, which required 379 individuals. As a result, studies with fewer than the required sample size were excluded from the analysis. Following this sensitivity analysis, the obtained prevalence was 54% [95% CI = 46–62%; $I^2 = 100\%$]. Following the sample size calculation, 69 studies were excluded from the sensitivity analysis and excluded in the meta-regression.

### Reporting bias

The Egger test found no publication bias ($p > 0.05$).

Table 2 shows the prevalence estimates for each subgroup. The mean age, the % of moderate-severe cases, and the BMI of the sample variables did not influence the heterogeneity when meta-regressed ($p > 0.05$).

### Level of evidence

The certainty of evidence was very low according to the GRADE system. Due to the use of non-probability sampling and the insufficient management of confounding variables, the domain "risk of bias" was classified as "severe". Due to high levels of inconsistency and sources of heterogeneity that subgroup analysis and meta-regression had failed to detect, the "inconsistency" domain was "very severe". When prevalence was evaluated as a secondary endpoint, the subject of "indirect evidence" was considered "very serious". Publishing bias was considered undetectable because a thorough search of the subject's literature, including grey literature, was conducted. Also, we discovered no potential conflicts of interest in the included studies (Table 3).

## Discussion

This systematic review assessed the evidence on OSA prevalence and its associated risk factors worldwide. When a meta-analysis only included studies with sufficient sample sizes, the prevalence of OSA was 54%. In addition, the qualitative synthesis revealed that high BMI, growing age, and male gender were the risk factors most frequently identified. While these findings are similar to those of a systematic review previously published by Senaratna and colleagues [7]. However, there were significant differences in the age groups, diagnostic criteria, and cut-off levels of the indexes used to report sleep apnea in the research.

In order to have a better understanding of OSA, it is critical to emphasize that its etiology is multifactorial [116, 117]. At least four major characteristics or phenotypes are known to play a role in OSA pathogenesis [118]. A study conducted in Oman sought to assess the relationship between BMI, age, and gender disparities in the prevalence

**Table 1** Characteristics of the included studies ($n$=99)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Abdel et al, 2022, Egypt[116] | 160 (all male) | 48.7 (5.6) | OSAS screening (160) and PSG (42) | AHI > 5 | 42 | Weight, neck circumference, systolic blood pressure, PaO[sub]2 and PaCO[sub]2 are the most useful predictors of suspecting OSAS. |
| Abraham et al, 2021, USA[22] | 456<br>263 male<br>193 female | 5.7 (3.2) | PSG | AHI ≥ 2 | 252 | Children with large tonsil size had 3.18 times the odds of OSA<br>Patients who reported their race as White had 0.28 times the odds of OSA;<br>Patients with more severe symptoms had 1.72 times the odds of OSA compared to patients with only snoring |
| Akkoyunlu et al, 2013, Turkey[67] | 241 (all male) | 42 (9.9) | OSAS screening (241) and PSG (42) | AHI ≥ 5 + symptoms (sleep attacks or EDS, unsatisfying sleep, fatigue or insomnia, witnessed heavy snoring and/or breathing pauses referred by the partner)<br>OR<br>AHI ≥ 15 | General: 34<br>AHI 5- 15: 11<br>AHI 15-30: 9<br>AHI > 30: 14 | Has not been reported |
| Al-Abri et al, 2011, Oman[10] | 608<br>405 male<br>203 female | Male: 45.3 (12.1)<br>Female: 39.8 (13.2) | PSG | AHI > 15 | General: 300<br>Male: 232<br>Female: 68 | In men, the prevalence of hypertension, IHD and hypothyroidism.<br>In women, the prevalence of COPD / asthma , IHD , diabetes and hypothyroidism. |
| Anuntaseree et al, 2005, Thailand[72] | 755<br>371 male<br>384 female | 10.2 (0.5) | OSA screening (755) and PSG (10) | AHI ≥1 | 10 | Has not been reported |
| Arora et al, 2022, USA[24] | 170 (all male) | 53.7 (3.1) | PSG | AHI ≥ 15 | 58 | BMI |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Arrazola-Cortés et al, 2017, Mexico[105] | 51<br>23 male<br>28 female | 54.1 (12.1) | PSG | Mild OSA: AHI ≥ 5 and < 15<br>Moderate OSA: AHI ≥ 15 and < 30<br>Severe OSA: AHI ≤ 30 | General: 22<br>Mild OSA: 10<br>Moderate OSA: 6<br>Severe OSA: 6 | Gender (male), BMI and neck perimeter |
| Bains et al, 2020, USA[25] | 456<br>256 male<br>193 female | 5.7 (3.2) | PSG | Severe OSA: AHI > 10 | 66 | African American race patients had 3.7 times the odds of severe OSA compared to with race patients (95% CI, 1.2-10.8).<br>Patients aged 2 to 3 years had 2.2 times the odds of severe OSA compared to children aged 4 to 6 years (95% CI, 1.2-4.0). |
| Bariş et al, 2017, Turkey[68] | 131<br>62 female<br>69 male | 101.9 (59.2) months | PSG | Mild OSA: AHI > 1 and < 5<br>Moderate OSA: AHI > 5 and < 10<br>Severe OSA: AHI > 10 | General: 44<br>Mild OSA: 13<br>Moderate OSA: 8<br>Severe OSA: 23 | The mean OHAI was signifi-<br>cantly higher in patients:<br>-With symptoms of chronic snoring compared with those with no chronic snoring ($p$=0.011).<br>-Who had apnea during sleep compared with those without sleep apnea ($p$=0.008). |
| Benn et al, 2021, Australia[52] | 82<br>41 male<br>41 female | 45.5 | PSG | Mild OSA: AHI ≥ 5 and < 15<br>Moderate OSA: AHI ≥ 15 and < 30<br>Severe OSA: AHI ≤ 30 | General: 72<br>Mild: 16<br>Moderate: 15<br>Severe: 41 | Has not been reported |
| Berger et al, 2012, USA[26] | 19,371 | Male 41.2 (11.2)<br>Female 41.2 (9.7) | OSA screening (19371) and PSG (2429) | Possible OSA: AHI ≥ 5 and ≤ 10<br>Definite OSA: AHI > 10 | Higher-risk drivers OSA<br>-Definite OSA: 1424<br>-Possible OSA: 253<br>Lower-risk drivers OSA<br>-Definite 156<br>-Possible OSA: 38 | Has not been reported |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Bruyneel et al, 2010, Belgium[95] | 2,093 | Patients under age 40: 34 (5)<br>Patients over age 40: 56 (10) | PSG | AHI > 5 | General: 781<br>Patients under age 40: 121<br>Patients over age 40: 660 | Compared to >40 years OSA patients, younger patients were more often male, African and obese (BMI>30). |
| Caia et al, 2020, Australia[53] | 22 (all male) | 23.8 (3.6) | Home-based PSG | Mild OSA: AHI ≥ 5 and < 15<br>Moderate OSA: AHI ≥ 15 and < 30<br>Severe OSA: AHI ≥ 30 | General: 10<br>Mild OSA: 7<br>Moderate OSA: 3<br>Severe OSA: 0 | Increased BMI and higher skinfold thickness |
| Campanholo et al, 2022, Brazil[36] | 701<br>317 male<br>384 female | 50.2 (13.3) | PSG | AHI ≥ 15 | 270 | Has not been reported |
| Celikhisar et al, 2019, Turkey[69] | 965 (all male) | 45.1 (5.5) | OSA screening (965) and PSG (110) | Mild OSA: AHI 5 -15<br>Moderate OSA: AHI 15 - 30<br>Severe OSA: AHI >30 | General: 69<br>Mild OSA: 35<br>Moderate OSA: 20<br>Severe OSA: 14 | BMI values and neck circumference. |
| Celikhisar et al, 2020, Turkey[70] | 1450 (all male) | 42.1 (5.5) | OSAS screening (1450) and PSG (162) | Mild OSA: AHI 5 -15<br>Moderate OSA: AHI 15 - 30<br>Severe OSA: AHI >30 | General: 127<br>Mild OSA: 39<br>Moderate OSA: 35<br>Severe OSA: 53 | BMI, neck circumference and waist/hip ratio |
| Chau et al, 2003, China[44] | 62<br>36 male<br>26 female | 6.8 (3.6) | PSG | AHI >1 | 22 | Snoring every night |
| Chen et al, 2021, China[45] | 93 (all male) | 28.8 (3.0) | PSG | AHI ≥ 5 | 19 | Has not been reported |
| Cho et al, 2013, Korea[82]. | 746<br>252 male<br>494 female | 59.3 (7.2) | PSG | Moderate OSA: AHI 15 > 30<br>Severe OSA: AHI ≥30 | General: 90 | Has not been reported |
| Chuanprasitkul et al, 2021, Thailand[73] | 189<br>119 male<br>70 female | Normal group: 81.1 (28.1) months<br>OSA group: 79.0 (31.4) months | PSG | Mild OSA: has not been reported<br>Moderate OSA: OAHI ≥ 5 and < 10<br>Severe OSA: OAHI ≥ 10 | General: 167<br>Mild: 62<br>Moderate: 47<br>Severe: 58 | Arousal index were predictors of pediatric OSA |
| Coussa-Koniski et al, 2020, Lebanon[104] | 663<br>506 male<br>157 female | 60.8 (16.0) | PSG | Mild OSA: AHI 5 - 15<br>Moderate OSA: AHI 15 - 30<br>Severe OSA: AHI > 30 | General: 526<br>Mild : 99<br>Moderate : 200<br>Severe : 227 | Gender (male), age and BMI class. |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Dashzeveg et al, 2021, Mongolia[117] | 205<br>105 male<br>100 female | 48.7 (12.6) | PSG | Mild OSA:AHI ≥ 5 and ≥ 15<br>Moderate OSA: AHU > 15 and < 30<br>Severe OSA: AHI ≥ 30 | General: 191<br>Mild : 50<br>Moderate : 41<br>Severe : 100 | BMI, neck/waist circumference, and blood pressure |
| de Menezes Júnior et al, 2021, Brazil[37] | 119 (all male) | 35.3 | PSG | Mild OSA: AHI ≥ 5 and ≤ 15<br>Moderate and severe OSA: AHI ≥ 15 | Mild OSA: 45<br>Moderate and severe OSA: 55 | Has not been reported |
| Deegan et al, 1996, Ireland[106] | 250<br>201 male<br>49 female | OSA group: 50 (11)<br>Non-OSA group: 45 (13) | PSG | AHI ≥ 15 | 136 (54%) | Gender (male). Female patients with OSA were more likely to be post-menopausal. |
| Del Bruto el at, 2021, Ecuador[115] | 180<br>64 male<br>116 female | 71.8 (7.2) | PSG | Mild OSA: 5-15<br>Moderate-to-severe OSA: >15 | Mild OSA: 83<br>Moderate-to-severe OSA: 38 | Has not been reported |
| Domany et al, 2018, USA[23] | 92<br>44 male<br>48 female | 4 - 11 years | PSG | OI > 2 | General: 40<br>Preterm children: 26<br>Term children: 14 | The risk for OSA could be stratified according to controller gain, plant gain, cardiorespiratory coupling and gestational age. |
| Dorkova et al, 2010, Slovakia[91] | non-Roma subjects: 137<br>Roma subjects: 23.<br>114 male<br>46 female | 50.0 (1.1) | PSG | AHI > 5 | General: 100<br>Roma subjects: 21<br>non-Roma subjects: 89 | Roma background and WC were independent predictors of AHI ($p$<0.001) |
| Dostálová et al, 2020, Slovakia[92] | 42<br>35 male<br>7 female | 64.6 (7.5) | PSG | Mild OSA: 5 - 14<br>Moderate OSA: 15 - 29<br>Severe OSA: ≥ 30 | General: 34<br>Mild OSA: 13<br>Moderate and Severe OSA: 21 | Has not been reported |
| Duarte et al, 2017, Brazil[38] | 456<br>290 male<br>166 female | 43.7 (12.5) | PSG | Mild OSA: AHI ≥ 5 and < 15<br>Moderate-Severe OSA: AHI ≥ 15 and < 30<br>Severe OSA: AHI ≥30 | General: 357<br>Moderate-Severe OSA: 237<br>Severe OSA: 130 | Age, BMI, neck circumference, prevalence of OSA was higher in males. |
| Durán et al, 2001, Spain[80] | 2148<br>1050 male<br>1098 female | OSA high risk:<br>-Male: 52.0 (9.9)<br>-Female: 55.5 (11.3)<br>OSA low risk:<br>-Male: 47.4 (10.8<br>-Female: 46.9 (10.5) | OSA Screening (2148) and PSG (555) | AHI ≥ 10 | OSA High-risk: 187<br>OSA low-risk: 15 | Hypertension |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Duong-Quy et al, 2018, Vietnam[107] | 667<br>374 male<br>293 female | 44 +12 | OSA screening and PSG | Mild OSA: 5-14<br>Moderate OSA: 15-30<br>Severe OSA: >30 | General: 57<br>Mild OSA: 22<br>Moderate OSA: 19<br>Severe OSA: 16 | Male |
| Drakou et al, 2021, Greece[99] | 272<br>200 male<br>72 female | 52.9 | PSG | Mild OSA: 5-14<br>Moderate OSA: 15-29<br>Severe OSA: ≥ 30 | General: 206<br>Mild OSA: 46<br>Moderate OSA: 75<br>Severe OSA: 85 | Has not been reported |
| Ferreira-Santos et al, 2021, Portugal[114] | 318 | 61 (11) | PSG | Mild OSA: 5-14<br>Moderate OSA: 15-29<br>Severe OSA: ≥ 30 | General: 203<br>Mild OSA: 111<br>Moderate OSA: 50<br>Severe OSA: 42 | There was an increasing prevalence of symptoms and comorbidities, the latter describing older and obese patients, and a substantial increase in some comorbidities, suggesting their beneficial use as combined predictors |
| Fietze et al, 2018, Germany[86] | 1.208<br>652 male<br>556 female | 54 | PSG | Mild-to-severe OSA: ≥ 5<br>Moderate-to-severe OSA: ≥ 15;<br>Severe OSA: ≥ 30 | Mild-to-severe OSA: 555 (45.9%)<br>Moderate-to-severe OSA: 256 (21%)<br>Severe OSA: 93 (8%) | Men, aged 60 years or older. Gender differences decreased with increasing age |
| Foster et al, 2017, USA[27] | 209<br>108 male<br>101 female. | 34.3 (±8.5) | PSG | AHI > 5 | General: 142 (68%)<br>Male: 92 (85.2% )<br>Female: 50 (49.5%) | Men |
| Franklin et al, 2013, Sweden[103] | 399 female | 48 (46–49) | PSG | OSA: ≥ 5<br>Moderate OSA: ≥ 15<br>Severe OSA: ≥ 30 | General: 200 (50%)<br>Mild OSA: 124 (31%)<br>Moderate OSA: 57 (14%)<br>Severe OSA: 23 (5.9%) | Overweight, age, hypertension, witnessed apnoea and snoring |
| Garbarino et al, 2016, Italy[101] | 283 male professional truck drivers | 42.3 (±8.3) | OSA Screening and PSG (139) | Mild OSA: 5-14<br>Moderate OSA: 15-30<br>Severe OSA: >30 | General: 101 (36%)<br>Mild OSA: 44 (16%)<br>Moderate OSA: 33 (12%)<br>Severe OSA: 24 (8%) | BMI, neck circumference and neck-chin angle |
| Ghosh et al, 2020, India[60] | 1000 | 51,4 (12,3) | OSA Screening (1000) and PSG (80) | Mild OSA: 5-15<br>Moderate OSA: 15-30<br>Severe OSA: >30 | General: 75 (36%)<br>Mild OSA: 44 (16%)<br>Moderate OSA: 33 (12%)<br>Severe OSA: 24 (8%) | Increased BMI and neck circunference |
| Ghoshal et al, 2010, India[61] | 714<br>590 male<br>124 female | 41 - 80 | PSG | AHI > 5 | 604 (84.59%) | Has not been reported |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Godoy et al, 2022, Brazil[39] | 62<br>11 male<br>51 female | 73 | PSG | Mild OSA: AHI ≥ 5 and ≤ 15<br>Moderate OSA: AHI > 15 and ≤ 30<br>Severe OSA: AHI > 30 | General: 45<br>Mild OSA: 17<br>Moderate OSA: 18<br>Severe OSA: 10 | Has not been reported |
| Gregório et al, 2008, Brazil[40] | 38<br>17 male<br>17 female | 8.4 (4.0) | PSG | Mild OSA: 1-5<br>Moderate OSA: 5-10<br>Severe OSA: >10 | General: 35 (92%)<br>Mild OSA: 16 (42.1%)<br>Moderate OSA: 11 (28.9%)<br>Severe OSA: 8 (22.1%) | Snoring, bruxism, nasal obstruction and restless legs during sleep.th present in 75% of the examined patients with severe disorder. |
| Guscoth et al., 2021, Australia[54] | 753 (all male) | 60.8 (10.9) | PSG | Mild OSA: 10-19<br>Moderate OSA: 20-29<br>Severe OSA: ≥ 30 | General: 396<br>Mild OSA: 196<br>Moderate OSA: 107<br>Severe OSA: 93 | OSA metrics were positively associated with serum triglyceride levels in men with a normal WC |
| Han et al, 2021, Korea[83] | 103 (all male) | 44.3 (8.1) | PSG | Moderate and severe OSA: >15 | 73 | BMI and cumulative flight time |
| Heraganahally et al, 2019, Australia[55] | 3078<br>1972 male<br>1767 female | 51.1 | PSG | Mild OSA: 5-15<br>Moderate OSA: 15-30<br>Severe OSA: >30 | General: 2569 (83.7%)<br>Mild OSA: (28.4%)<br>Moderate: (22.3%)<br>Severe: (33.0%) | Male, age and higher BMI. Among individuals with severe AHI, hypertension, heart disease and diabetes. |
| Heraganahally et al, 2021, Australia[56] | 340<br>173 male<br>167 female | 47 (38-57) | PSG | Mild OSA: 5-15<br>Moderate OSA: 15-30<br>Severe OSA: >30 | General: 297<br>Mild OSA: 77<br>Moderate OSA: 69<br>Severe OSA: 151 | Has not been reported |
| Hu et al, 2019, China[46] | 196<br>161 male<br>35 female | 18 - 70 | PSG | Mild OSA: 5-15<br>Moderate OSA: 15-30<br>Severe OSA: ≥30 | General: 168<br>Mild OSA: 28<br>Moderate OSA: 31<br>Severe OS: 109 | Gender, BMI and neck circumference. |
| loachimescu et al, 2020, USA[28] | 500<br>400 male<br>100 female | 52.5 (41.8– 62.5) | PSG | Mild OSA: 5-15<br>Moderate OSA: 15-30<br>Severe OSA: ≥30 | General: 423<br>Mild OSA: 133<br>Moderate OSA: 135<br>Severe OSA: 155 | Has not been reported |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Ioannidou et al, 2021, Greece[100] | 3791<br>2678 male<br>1113 female | 57.2 (13.6) | `PSG | Mild OSA: 5-15<br>Moderate OSA: 15-30<br>Severe OSA: ≥30 | General: 3271<br>Mild OSA: 534<br>Moderate OSA: 918<br>Severe OSA: 1819 | Age, BMI, the number of cigarettes/day, pack/Years, and Fagerstrom Test for Nicotine Dependence were higher in patients with more severe OSA with more prevalent CVD comorbidities |
| Jalilolghadr et al, 2022, Iran[97] | 112<br>73 male<br>39 female | 5.8 | PSG | Mild OSA:1 - 4<br>Moderate OSA: 5 - 10<br>Severe OSA: >10 | General: 99<br>Mild OSA: 14<br>Moderate OSA: 19<br>Severe OSA: 66 | Has not been reported |
| Jia et al, 2021, China[47] | 107<br>63 male<br>44 female | 31,7 (11.9) | PSG | Mild OSA: 5-15<br>Moderate OSA: 15 - 30<br>Severe OSA: ≥30 | General: 63<br>Mild OSA: 25<br>Moderate OSA: 20<br>Severe OSA: 18 | Increased risk for EPVS in OSA is a potential contributor to increased stroke risk in OSA |
| Jung et al, 2017, USA[29] | 352<br>194 male<br>158 female | 58 | PSG | Mild OSA: 5-14<br>Moderate OSA: ≥ 15 | General: 267<br>Mild OSA: 126<br>Moderate OSA: 141 | Male sex, age, BMI, and presence of hypertension. |
| Kanda et al, 2018, Brazil[41] | 255<br>137 male<br>118 female | 55,7 (10.6) | PSG | AHI ≥15 | 91 | Female, older and with higher BMI |
| Katz et al, 2014, Canada[89] | 222<br>121 male<br>101 female | 12.1 (7.0 – 17.9) | PSG | AHI > 5<br>or<br>OAI ≥ 1 | 47 | - |
| Kim et al, 2004, Korea[84] | 457<br>309 male<br>148 female | Male with snoring: 49.1<br>Male without snoring: 48.4<br>Female with snoring: 54.3<br>Female without snoring: 48.8 | PSG | AHI ≥ 5 | 160 | WHR, BMI, and systolic blood pressure<br>men aged 50 to 59 years<br>women increased with age |
| Klawe et al, 2005, Poland[108] | G1: 21 fast-rotating shift worked police officers<br>G2: 21 subjects age-matched (control group) | G1: 47.1 (3.2)<br>G2: 42,0 (2.8) | PSG | AHI ≥5 | Police officers: 8<br>Control volunteers: 8 | Overweight or obesity |
| Kobayashi et al, 2013, Japan[93] | 152 | 6-12 | OSA Screening (152) and PSG (8) | AHI ≥5 | 6 | Has not been reported |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Koyama et al, 2012, Brazil[42] | 745<br>All male | 35.6 (9.6) | PSG | Mild OSA: 5–15;<br>Moderate OSA: 15–30;<br>Severe OSA: >30 | General: 261<br>Mild OSA: 405<br>Moderate OSA: 188<br>Severe OSA: 151 | Obese, older, time employed as a shift worker, and had consumed more alcohol. |
| Lee et al, 2019, Korea[85] | 105<br>56 male<br>59 female | 40.6 (11.6) | PSG | Mild OSA: 5 - 14<br>Moderate OSA: 15 - 29<br>Severe OSA: ≥ 30 | General: 37<br>Mild OSA: 22<br>Moderate OSA: 9<br>Severe OSA: 6 | Older, BMI and predominant with male. |
| Li et al, 2014, China[48] | 350<br>302 males<br>48 females | 42.9 (11.0) | PSG | Mild OSA: 5 - 14<br>Moderate OSA: 15 - 29<br>Severe OSA: ≥ 30 | General: 315<br>Mild OSA: 44<br>Moderate OSA: 57<br>Severe OSA: 214 | Age, BMI, likelihood and hypertension. |
| Liu et al, 2020, China[49] | 4297<br>3416 male<br>881 female | Male: 40<br>Female: 48 (non-OSA);<br>50 (OSA) | PSG | Mild OSA: 5 - 14<br>Moderate OSA: 15 - 29<br>Severe OSA: ≥ 30 | General: 3679<br>Mild OSA: 713<br>Moderate OSA: 716<br>Severe OSA: 2250 | BMI, neck circumference, WC, hip circumference and waist-to-hip ratio |
| McArdle et al, 2020, Austrália[57] | 935<br>459 male<br>476 female | 22.2 | PSG | Mild-to-severe OSA: ≥ 5<br>Moderate-to-severe OSA: ≥ 15; | General: 192<br>Moderate-severe OSA: 34 | Has not been reported |
| Morell-Garcia et al, 2021, Spain[77] | 168<br>Children<br>-50 male<br>-34 female<br>Adults: has not been reported | Children: 8.1<br>Adults: has not been reported | PSG | Children<br>-Mild OSA: AHI ≥ 1 and ≤ 5<br>-Moderate and severe OSA: AHI ≥ 5<br>Adults<br>AHI ≥ 5 | Children<br>-Mild OSA: 28<br>-Moderate and severe OSA: 18<br>Adults: 51 | The prevalence of fathers with OSA increases with the children's severity in the group of children with moderate-severe OSA. Having moderate-severe pediatric OSA were more than 4 times higher among children with a father with OSA |
| Mosharraf-Hossain et al, 2015, Bangladesh[118] | 2250 | 39.8 (9.4) | OSA Screening (2250) and PSG (120) | OSAH: AHI >5 and<br>OSAHS: AHI >5 + excessive daytime sleepiness | OSAH:<br>-Snoring sample: 29<br>-non-snoring sample: 1<br>OSAHS:<br>-Snoring sample: 9<br>-non-snoring sample: 0 | Male gender, age, obesity (defined by a high BMI), waist/hip ratio |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Mungo et al, 2021, Belgium[96] | 264<br>131 male<br>133 famele | 18-30 years | PSG | OSAH: AHI> 5 | 49 | Atypical depression, male, snoring, presence of at least one cardiometabolic alteration, mass index body weight greater than 30 $kg/m^2$ and ferritin greater than or equal to 150 g/L |
| Mysliwiec et al, 2013, USA[30] | 725<br>676 male<br>49 female | 35.5 (8.6) | PSG | Mild OSA: 5 –15<br>Moderate to severe OSA: > 15) | General OSA: 390<br>Mild OSA: 207<br>Moderate to severe OSA: 183 | Older military personnel and males were more likely, an elevated BMI and the absence of an anxiety diagnosis were also associated with moderate-to-severe OSA |
| Neruntarat et al, 2010, Thailand[74] | 2685 | 43.4 (9.3) | OSA screening (2685) and PSG (196- 102 snorers and 94 non-snorers) | AHI >5 | Snorers: 40<br>non-snorers: 2 | Male gender, age >45 years, obesity defined by BMI of>25 $kg/m^2$, alcohol ingestion, smoking, and hypertension. |
| Pien et al, 2014, USA[109] | 105 woman | 26.7 (7.2) | PSG | General OSA: AHI ≥5<br>Mild OSA: 5-14<br>Moderate OSA: 15-29<br>Severe OSA: ≥30 | First semester: 11<br>Third semester: 28<br>-Mild OSA: 23<br>-Moderate OSA: 4<br>-Severe OSA: 1 | First trimester BMI and maternal age were significantly associated with third trimester OSA. |
| Powers et al, 2009, USA[32] | 62<br>59 male<br>3 female | 40.5 (7.8) | PSG | Mild or moderate OSA: AHI ≥ 5 and < 30 | 41 | Has not been reported |
| Quintana-Gallego et al, 2004, Spain[78] | 1745<br>1386 male<br>359 female | Male: 52.9 (11)<br>Female: 57.8 (9.5) | PSG OR polygraphy | AHI>10 | General: 1166<br>-Male: 970<br>-Female: 196<br>Overnight PSG: 233<br>Nap PSG: 342<br>Polygraphy: 591 | Has not been reported |
| Randby et al, 2013, Norway[109] | 16,302<br>479 after screening<br>273 male<br>206 female | 47.9 | OSA Screening (16,3052) and PSG (479) | Mild to moderate OSA: 5 - 29.9<br>Severe OSA: ≥ 30 | 266 | OSA was an independent predictor of impaired endothelial function in women |
| Ratnavadivel et al, 2009, Australia[58] | 253<br>169 male<br>84 female | Non OSA: 47.5 (1.9)<br>OSA:<br>54.1 (1.1) | PSG | AHI ≥ 15 | 171 | This group was significantly older, comprised relatively more males, and had a higher BMI |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Reddy et al, 2009, India[63] | 2505<br>1263 male<br>1242 female | 41 (9) | Snorers screening (2505) and PSG (365- 287 snorers<br>and 73 non-habitual snorers) | AHI ≥ 5 | Habitual snorers: 94<br>Non-habitual snorers: 3 | Increasing age, male gender, socioeconomic status score, habitual smoking, hypertension, obesity, high WHR, PPNC > 90, and high subscapular and suprailiac skinfold thicknesses |
| Reddy et al, 2014, India[62] | 425 children<br>389 male<br>36 female | 2 months - 18 years | PSG | Mild OSA: 1-5<br>Moderate OSA: 5-10<br>Severe OSA: ≥ 10 | General OSA: 211<br>Mild OSA: 99<br>Moderate OSA: 34<br>Severe OSA: 78 | Has not been reported |
| Roche et al, 2021, South Africa[110] | 75<br>22 male<br>53 male | 66.1 (10.7) | PSG | AHI ≥ 15 | 22 | Participants were older, had higher BMI, higher WC, higher prevalence of Mets and greater CMR score |
| Sadeghniiat-Haghighi et al, 2015, Iran[98] | 603<br>451 male<br>152 female | 45.8 (12.7) | PSG | Mild OSA: 5 - 14<br>Moderate OSA: 15 - 29<br>Severe OSA: ≥ 30 | General OSA: 438<br>Mild OSA: 124<br>Moderate OSA: 114<br>Severe OSA: 201 | Has not been reported |
| Sasai-Sakuma et al, 2016, Japan[94] | 2389 male | 48.2 (7.6) | OSA Screening (2389) and PSG (422) | AHI ≥ 15<br>or<br>AHI ≥ 5 + ESS ≥ 11 | General: 235<br>AHI ≥ 15: 224<br>AHI ≥ 5 + ESS ≥ 11: 11 | Has not been reported |
| Scarlata et al, 2013, Italy[102] | 254<br>154 male<br>100 female | 65.8 (12.1) | Cardio-respiratory polygraphy (219) or PSG (35) | Mild OSA: 10 - 20<br>Moderate OSA: 20-30<br>Severe OSA: ≥ 30 | General OSA: 141<br>Mild OSA: 46<br>Moderate 35<br>Severe 60 | Has not been reported |
| Selvadurai et al, 2019, Canada[90] | 113 children<br>75 male<br>38 female | No-OSA: 2.2 (0.6)<br>OSA: 2.2 (0.5) | Overnight PSG | Mild OSA: OAHI ≥1.5 to <5<br>Moderate OSA: OAHI ≥5 to <10<br>Severe OSA: OAHI ≥10 | General: 66<br>Mild OSA: 13<br>Moderate-to-severe OSA: 53 | Overweight and obese individuals |
| Sharma et al, 2006, India[64] | - | 42.7 (9.0) | OSA Screening (2150) and PSG (151) | AHI > 5 | General: 38<br>Habitual snorers: 36<br>Non habitual snorers: 2 | Male gender, age 45 years, obesity defined by a BMI of 25 kg/m$^2$, and WHR of 0.80 in women and 0.95 in men |
| Singh et al, 2017, India[65] | 1512<br>1026 male<br>485 female | 42.6 (11.2) | OSA Screening (1512) and PSG (311) | AHI ≥ 5 | General: 62<br>OSA high-risk: 44<br>OSA low-risk: 18 | Gender (males) |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Sogut et al, 2005, Turkey[71] | 1198<br>582 male<br>616 female | 8.1 (1.9) | OSA Screening (1198) and PSG for snoring children (28) | AHI > 3 | 11 | Has not been reported |
| Tapia et al, 2016, USA[59] | 197<br>114 male<br>83 female | 5–12 | PSG | AHI ≥ 2 | 19 | OSAS is associated with chorioamnionitis and multiple gestation in ex-preterm children. |
| Tawaranurak et al, 2019, Thailand[75] | 929<br>622 male<br>307 female | 18 - 85 | PSG | Mild OSA: AHI ≥5 and <15<br>Moderate OSA: AHI ≥15 and ≤30<br>Severe OSA: AHI >30 | General OSA: 795 ,<br>Mild OSA: 215<br>Moderate OSA: 167<br>Severe OSA: 413 | Male gender, age ≥50 years,<br>BMI >25 kg/m$^2$, neck circumference >40 cm and waist to height ratio >0.6 |
| Togeiro et al, 2013, Brazil[43] | 1,042 | Non-OSA: 37.3 (12.3)<br>Mild OSA: 48.3 (13.6)<br>Moderate-to-severe OSA: 53.3 (13.3) | PSG | Mild OSA: AHI 5 - 14.9<br>Moderate to severe OSA: AHI ≥ 15 | General: 396<br>Mild OSA: 221<br>Moderate-to-severe: 175 | Older, more obese, and had greater mean values for waist and neck circumferences as well as for lipid levels |
| Tripathi et al, 2017, India[66] | 552 | 35 - 55 | OSA Screening (552) and PSG (120) | AHI >5 | 57 | Lifestyle stress, sleep deprivation, and upper airway inflammation |
| Tufik et al, 2010, Brazil[8] | 104<br>469 male<br>573 female | 42 (14) | PSG | AHI ≥ 5 + at least one of the following complaints: loud snoring, daytime sleepiness, fatigue, and breathing interruptions during sleep.<br>OR<br>AHI ≥ 15 | General OSA: 398<br>Mild OSA: 222<br>Moderate-to-severe OSA: 176 | Has not been reported |
| Urschitz et al, 2010, Germany[87] | 1144<br>583 male<br>561 female | 9.6 (0.7) | OSA Screening (1144) and Home PSG (183) | AHI ≥ 1 | OSA high-risk: 20<br>OSA low-risk: 2 | BMI, history of allergy, a composite questionnaire score, and two oximetry-based criteria. |
| Valenza et al, 2012, Spain[79] | 1008<br>804 male<br>205 female | 18 - 80 years | PSG | AHI ≥ 5 | 893 | Hypertension, diabetes and cardiac pathology |
| Veeravigrom et al, 2016, Thailand[76] | 166<br>111 male<br>55 female | 8.6 (4.6) | PSG | Mild OSA: 1 - 5<br>Moderate OSA: 5 - 10<br>Severe OSA: ≥ 10 | General: 154<br>Mild OSA: 43<br>Moderate OSA: 44<br>Severe OSA: 67 | Has not been reported |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Vega-Osorio et al, 2020, Colombia[111] | 575<br>273 male<br>302 female | 51.0 (13.7) | PSG | Mild OSA: 5 - 14<br>Moderate OSA: 15 - 29<br>Severe OSA: ≥ 30 | General: 420<br>Mild OSA: 142<br>Moderate OSA: 169<br>Severe OSA: 109 | Has not been reported |
| Wahida et al, 2013, Malaysia[112] | 289 | 45.4 (7.0) | PSG | Mild OSA: AHU ≥ 5 and <15<br>Moderate OSA: AHI ≥ 15 and < 30<br>Severe OSA: AHI ≥ 30 | General: 128<br>Mild OSA: 83<br>Moderate OSA: 26<br>Severe OSA: 19 | Age, BMI, neck circumference and hypertension |
| Wahner-Roedler et al, 2007, USA[33] | 522<br>267 male<br>255 female | 57 years (range, 18-76 years) | PSG | AHI ≥ 15<br>or<br>AHI ≥ 5 and < 15 + insomnia, excessive daytime sleepiness, mood disorder, impaired cognition, hypertension, ischemic heart disease, or history of stroke. | 406 | Has not been reported |
| Wali et al, 2017, Saudi Arabia[113] | 2682<br>1286 male<br>1396 females | 40.7 (6.5) | Snoring screening (2682) and PSG (375) | AHI ≥ 5 | 235 | Male gender, age ≥50 years, obesity as defined by a BMI ≥30 kg/m 2, and a history of hypertension |
| Wiebracht et al, 2017, USA[34] | 342<br>182 male<br>160 female | 11.3 (2.4) | PSG | Mild OSA: AHI ≥ 1 and < 5<br>Moderate OSA: AHI ≥ 5 and < 10<br>Severe OSA: AHI ≥ 10 | General OSA: 170<br>Mild OSA: 109<br>Moderate OSA: 34<br>Severe OSA: 27 | Has not been reported |
| Xie et al, 2011, EUA[35] | 1890<br>1731 male<br>159 female | 43.7 (11.5) | OSA screening (1833) and PSG (65) | Mild OSA: AHI ≥ 5 and ≤ 15<br>Moderate OSA: AHI < 15 and < 30<br>Severe OSA: ≥ 30 | General OSA: 51<br>Mild OSA: 22<br>Moderate OSA: 20<br>Severe OSA: 31 | Higher BMI, higher neck circumference, and lower minimum oxygen saturation |
| Xu et al, 2006, China[51] | 50 | 7.8 (3.2) | PSG | AHI > 5 | 31 | Observable apnea during sleep, nocturnal enuresis, intrusive naps, mouth breathing, enlarged tonsils, and radiologic features of upper airway narrowing due to adenoid hypertrophy |

**Table 1** (continued)

| Author, years, country | Sample size and type (male; female) | Mean (SD) age or range | Diagnostic methods | OSA or OSAS definition | Results number | Factor risk |
|---|---|---|---|---|---|---|
| Xu et al, 2020, China[50] | 1578<br>1060 male<br>518 female | OSAS children: 5.7<br>non-OSAS children: 6.0 | PSG | AHI ≥ 1 | 1008 | Snoring ≥ 3 months, male gender, preterm birth, breastfeeding, obesity, Neck circumference ≥ 30 cm, Neck /height ratio ≥ 0.25, tonsillar and adenoid hypertrophy. |
| Zacharias et al, 2021, Germany[88] | 529<br>247 male<br>282 female | 52.2 | PSG | Mild OSA: 5 - 15<br>Moderate OSA: 15 - 30<br>Severe OSA: ≥ 30 | General OSA: 209<br>Mild OSA: 125<br>Moderate OSA: 52<br>Severe OSA: 32 | Has not been reported |
| Zamarrón et al, 2006, Spain[81] | 187<br>147 male<br>40 female | 57.9 (12.8) | PSG | AHI ≥ 10 | 111 | COPD |

*OSA*, obstructive sleep apnea; *OSAS*, obstructive sleep apnea syndrome; *PSG*, polysommography; *AHI*, apnea-hypopnea index; *EDS*, excessive daytime sleepiness; *IHD*, ischemic heart disease; *COPD*, chronic obstructive pulmonary disease; *OI*, obstructive apnea-hypopnea index; *BMI*, body mass index; *OHAI*, obstructive hypopnea apnea index; *CVD*, cardiovascular disease; *EPVS*, enlarged perivascular space; *WHR*, waist-hip ratio; *PPNC*, percent predicted neck circumference; *WC*, waist circumference; *CMR*, cardiovascular magnetic resonance

of Obstructive Sleep Apnea Syndrome (OSAS) in the country's population. They discovered that the male gender and obesity pose a greater risk than the female gender in the same age group. However, age is the most important predictor in women, with postmenopausal women being at a higher risk [6]. In this review, no single risk factor identified in the included articles explained the heterogeneity in the meta-regression analysis, indicating the possibility of multifactorial risk influencing this outcome.

The BMI was the most commonly reported risk factor in the studies, followed by age and gender, and BMI was reported more frequently in men. Other factors found in fewer studies included hypertension, cigarette smoking, and alcohol consumption. These findings are consistent with the findings of other studies, which identified male gender, older age, and higher BMI as risk factors [4, 5, 7]. Several included studies showed increasing OSA prevalence with increasing age, being significant for countries with older or aging populations. Therefore, the predominance of BMI and the male gender should be considered, particularly when planning risk-reduction interventions. Positive associations were found between OSA and waist-to-hip ratio, larger neck circumference, hypertension, smoking, snoring, and sleepiness [5]. Additionally, ethnicity was considered a risk factor in three studies: one linked white race to a higher likelihood of OSA [19]; another found that African Americans had a higher likelihood of having severe OSA than white patients [22]; and the third found that African patients had a higher likelihood of having a higher AHI [92].

Ninety-eight of the 99 articles chosen were eligible for meta-analysis and were divided into subgroups to increase the reliability of the analysis. When the age group was considered in the subgroup analysis, the prevalence of OSA in adults was 57%. However, the prevalence was higher in the elderly subgroup, at 69%, with the lowest prevalence in the subgroup of samples made up entirely of children, with a 50% estimate. A study of Chinese children [119] found a prevalence of OSAS ranging from 4.8 to 40.3%, depending on the cut-off point used, with male gender, obesity, and amygdala size associated with OSAS [119].

Regarding the classification of OSA, a subgroup analysis was performed concerning the severity of diagnosed OSA using the following classifications: "mild", "mixed", "severe", "mild to moderate", "moderate to severe", and "not classified". The classifications with the highest prevalence occurred in "mild to moderate" (69%), followed by "mixed" (68%), and with the lowest prevalence in "severe" (14%). Another subgroup pertains to the included countries, in which we found that 34 countries had at least one study that sought to

**Table 2** Estimates for each subgroup

| *Variant* | Sample number | *Prevalence by subgroup* | *IC95%* | $I^2$ |
|---|---|---|---|---|
| Age group (mean age) | 47634 | 0.56 | [0.51; 0.61] | 99% |
| Children and teenagers (2.2–11.3) | 4881 | 0,51 | [0.38; 0,64] | 98% |
| Adults (22.2–66.1) | 41797 | 0.57 | [0.51; 0.62] | 99% |
| Elderly (71.8–73) | 242 | 0.69 | [0.63; 0.74] | 0%, |
| Adults and elderly (not subdivided) | 714 | 0.85 | [0.82; 0.87] | Not applied |
| PSG | 47370 | 0.57 | [0.51; 0.62] | 99% |
| Triage | 6413 | 0.52 | [0.41; 0.63] | 99% |
| Total PSG | 40957 | 0.58 | [0.52; 0.64] | 99% |
| Type | 47634 | 0.56 | [0.51; 0.61] | 99% |
| Syndrome | 13242 | 0.52 | [0.42; 0.61] | 99% |
| OSA | 34392 | 0.58 | [0.52; 0.64] | 99% |
| Country | 47634 | 0.56 | [0.51; 0.61] | 99% |
| Egypt | 42 | 0.12 | [0.04; 0.26] | |
| USA | 6156 | 0.56 | [0.44; 0.68] | 99% |
| Turkey | 473 | 0.60 | [0.40; 0.78] | 95% |
| Oman | 608 | 0.49 | [0.45; 0.53] | |
| Mexico | 51 | 0.43 | [0.29; 0.58] | |
| Australia | 5649 | 0.54 | [0.30; 0.78] | 100% |
| Belgium | 2357 | 0.28 | [0.16; 0.41] | 97% |
| Brazil | 4460 | 0.55 | [0.36; 0.73] | 99% |
| China | 6733 | 0.65 | [0.46; 0.81] | 99% |
| Korea | 1411 | 0.37 | [0.15; 0.63] | 99% |
| Thailand | 1314 | 0.67 | [0.22; 0.98] | 99% |
| Lebanon | 663 | 0.79 | [0.76; 0.82] | |
| Mongolia | 205 | 0.93 | [0.89; 0.96] | |
| Ireland | 250 | 0.54 | [0.48; 0.61] | |
| Non-reported | 160 | 0.78 | [0.49; 0.97] | 87% |
| Ecuador | 180 | 0.67 | [0.60; 0.74] | |
| Slovakia | 42 | 0.50 | [0.34; 0.66] | |
| Greece | 4063 | 0.82 | [0.70; 0.91] | 95% |
| Spain | 3498 | 0.64 | [0.51; 0.76] | 98% |
| Vietnam | 93 | 0.61 | [0.51; 0.71] | |
| Germany | 1869 | 0.33 | [0.16; 0.53] | 97% |
| Portugal | 318 | 0.64 | [0.58; 0.69] | |
| Sweden | 399 | 0.51 | [0.46; 0.56] | |
| Italy | 370 | 0.73 | [0.38; 0.96] | 98% |
| India | 1987 | 0.59 | [0.29; 0.87] | 100% |
| Iran | 715 | 0.81 | [0.64; 0.93] | 93% |
| Canada | 335 | 0.39 | [0.08; 0.76] | 98% |
| Japan | 430 | 0.57 | [0.50; 0.63] | 2% |
| Poland | 42 | 0.38 | [0.24; 0.54] | 0% |
| Bangladesh | 60 | 0.50 | [0.37; 0.63] | |
| Norway | 479 | 0.56 | [0.51; 0.60] | |
| Singapure | 425 | 0.50 | [0.45; 0.55] | |
| Africa | 75 | 0.29 | [0.19; 0.41] | |
| Taiwan | 166 | 0.93 | [0.88; 0.96] | |
| Colombia | 575 | 0.73 | [0.69; 0.77] | |
| Malaysia | 289 | 0.44 | [0.38; 0.50] | |
| Saudi Arabia | 692 | 0.40 | [0.17; 0.66] | 97% |
| OSA classification | 47370 | 0.57 | [0.51; 0.62] | 99% |

**Table 2** (continued)

| *Variant* | Sample number | *Prevalence by subgroup* | *IC95%* | $I^2$ |
|---|---|---|---|---|
| Mild | 725 | 0.40 | [0.36; 0.43] | Not applied |
| Mild to moderate | 59 | 0.69 | [0.57; 0.81] | Not applied |
| Moderate to severe | 1019 | 0.37 | [0.08; 0.73] | 99% |
| Severe | 465 | 0.14 | [0.11; 0.18] | Not applied |
| Mixed | 27041 | 0.68 | [0.61; 0.73] | 99% |
| No classification | 18070 | 0.46 | [0.39; 0.54] | 99% |
| Sample origin | 47634 | 0.56 | [0.51; 0.61] | 99% |
| Drivers | 2145 | 0.45 | [0.00; 0.99] | 99% |
| PSG Lab | 31460 | 0.65 | [0.59; 0.71] | 99% |
| Long distance drivers | 42 | 0.81 | [0.66; 0.91] | |
| Military personal (PSG Lab) | 954 | 0.47 | [0.27; 0.68] | 91% |
| Rugby league athletes | 22 | 0.45 | [0.24; 0.68] | |
| General population | 9290 | 0.40 | [0.31; 0.50] | 98% |
| Heavy equipment users | 110 | 0.63 | [0.53; 0.72] | |
| Bus drivers | 162 | 0.78 | [0.71; 0.84] | |
| Truck drivers | 116 | 0.87 | [0.80; 0.93] | |
| Airplane drivers | 103 | 0.71 | [0.61; 0.79] | |
| Unclear | 107 | 0.59 | [0.49; 0.68] | |
| Policemen | 21 | 0.38 | [0.18; 0.62] | |
| Age matched group | 21 | 0.38 | [0.18; 0.62] | |
| Railroad workers | 745 | 0.19 | [0.16; 0.22] | |
| Pregnant women | 1040 | 0.28 | [0.13; 0.45] | 92% |
| Shift workers (iron ore mining) | 119 | 0.84 | [0.76; 0.90] | |
| Parents of children | 84 | 0.61 | [0.49; 0.71] | |
| Public transport drivers | 422 | 0.56 | [0.51; 0.60] | |

investigate the relationship between OSA and their population. Among all the continents, Asia had the most countries, with 13, followed by Europe, with 11. However, the continents with the most studies performed were Asia, with 35, followed by America, with 29. These numbers emphasize the importance of conducting additional studies in Africa and Oceania, which total three countries and nine studies aimed at understanding the relationship between this population and OSA.

The most significant strengths of this systematic review are related to the fact that the included studies were global in scope, with no language restrictions and no age restrictions. In addition, only studies that used PSG to diagnose OSA were considered. A thorough search of six databases and the grey literature was also conducted. Nonetheless, it is worth noting that the GRADE system assigned a very low level of certainty of evidence. The explanation stems from the studies' risk of bias assessment, which revealed that eight had a moderate risk of bias. In addition, these studies lacked clarity regarding the criteria used for OSA diagnosis and outcomes and uncontrolled confounding factors.

Regarding diagnosis criteria, some studies used a screening questionnaire on the study population before selecting a convenience sample and performing the PSG on them alone. Furthermore, other studies were based on a specific population with a convenience sample, which may have biased the estimate. Due to their morbidity profiles and other phenomena, such as the work effect, this convenience sample of drivers, pilots, athletes, military personnel, pregnant women, and others did not represent the general population. Subgroup analyses were performed to stratify categorical confounders that could overestimate the estimates generated in some population groups.

The study was also limited by the PSG conducted. Sleep studies are classified as type I, type II, type III, or type IV, with type I currently being considered the standard reference diagnostic test for OSA because it is conducted in a sleep laboratory and observed by a technician, while the other studies are unattended [120]. Nonetheless, some studies that used PSG did not report the type of sleep study used or conducted the other types, which may have acted as a confounding factor for the

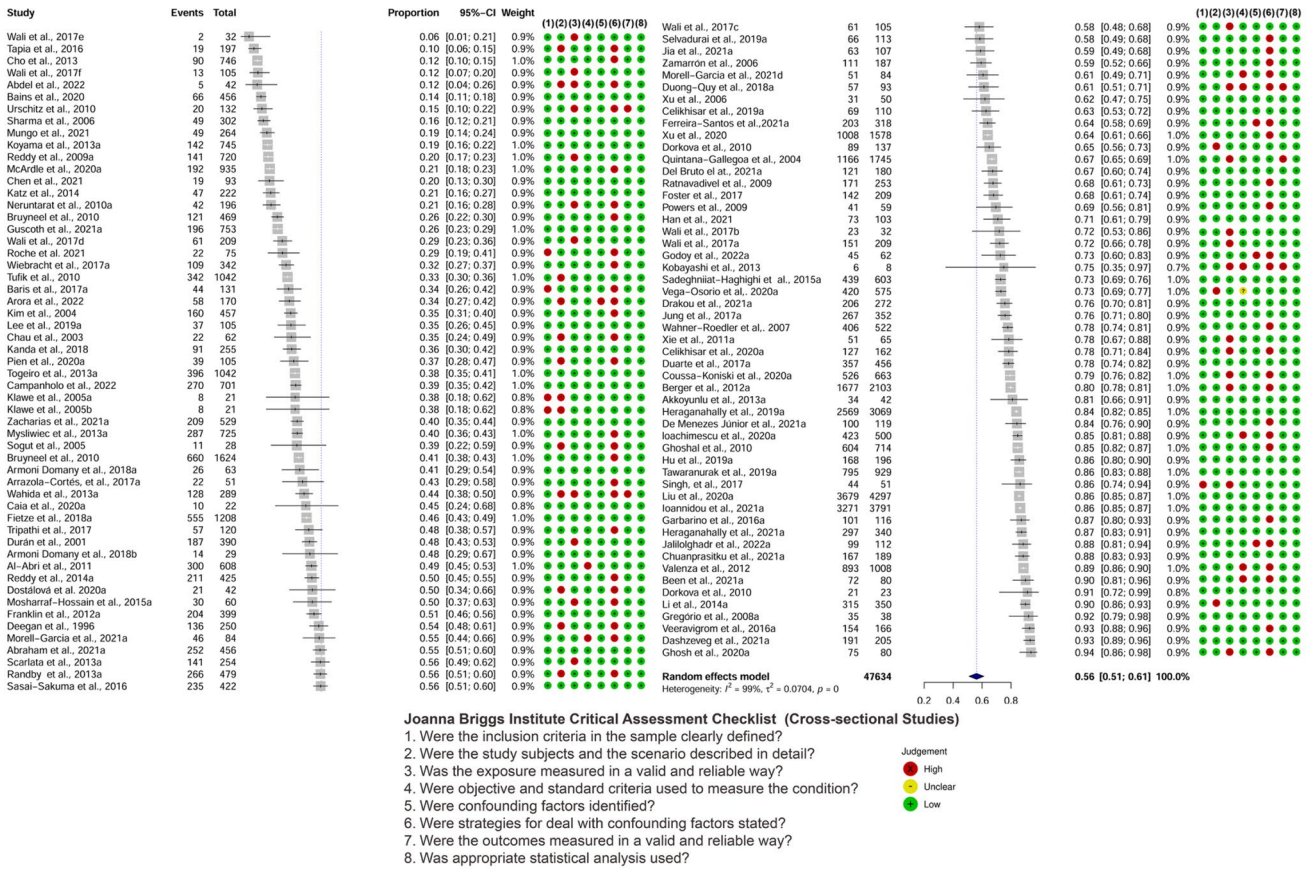


**Fig. 3** Forest plot of the meta-analysis of the prevalence of OSA displaying risk-of-bias judgements for each study included

estimates generated, given that type I has a higher cost than the others.

The importance of the current study lies in raising awareness of the high prevalence of OSA in the global population and across age groups, highlighting the need for public initiatives for discovery and for effective treatment. Continuous positive airway pressure (CPAP) is the standard treatment for OSA [121]. CPAP provides adequate upper airway stability through pressurization. Benefits may include improvement in cardiovascular comorbidities, decrease in excessive daytime sleepiness, and improvement in cognitive function and quality of life [121].

Additional treatment options can be used alone or combined, considering the condition's multifactorial etiology. These include using a mandibular advancement device [121], performing oropharyngeal exercises, and engaging in functional exercises that involve breathing, chewing, swallowing, and speaking [122]. However, studies on the long-term effects of speech-language therapy combined with functional and oropharyngeal exercises are still lacking. In contrast, CPAP use and the mandibular advancement device have been shown to successfully treat OSA in follow-ups [123–125].

## Conclusion

Approximately half of the people have OSA worldwide. Although the literature cites high BMI, increased age, and male gender as risk factors, these covariates did not influence the heterogeneity existing by meta-regression. Based upon the level of certainty, the results of this investigation should be with caution. We suggest studies with better methodological qualities.

## Other information

### Registration

The PROSPERO (International Prospective Registry of Systematic Reviews - Center for Reviews and Dissemination University of York-CRD42021265627) website has the protocol for this systematic review listed.

**Table 3** Analysis of information quality through GRADE

| **Research question:** What is the prevalence of OSA and risk factors in a general population? | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Certainty assessment** | | | | | | | | **Summary of findings** | | |
| **Participants (studies) follow-up** | **Risk of bias** | **Inconsistency** | **Indirectness** | **Imprecision** | **Publication bias** | **Overall certainty of evidence** | | **Study event rates (%)** | | **Anticipated absolute effects** |
| | | | | | | | | **Events** | **n** | **Prevalence risk** | **Prevalence (CI95%)** |
| **Prevalencia OSA população geral.** (98 observational studies) | Serious[a] | Very serious[b] | Very serious[c] | Not serious | None | ⨁◯◯◯ Very low | | 29219 | 47634 | 56 per 100 | 0.56 (0.51 – 0.61) |

Explanations

[a]Lack of adequate control of confounding factors and use of non-probability sampling

[b]High inconsistency and source of unidentified heterogeneities by subgroup analysis and meta-regression

[c]Prevalence was assessed as a secondary outcome

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**Data availability** Since no datasets were created or analyzed for this topic, data sharing is not applicable.

## Declarations

**Ethics approval** There are no studies by any of the writers in this article that used humans or animals as subjects.

**Conflict of interest** The authors declare no competing interests.

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