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Prevalence of sleep-disordered breathing in the general population: the HypnoLaus study

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Summary

Background—Sleep-disordered breathing is associated with major morbidity and mortality. However, its prevalence has mainly been selectively studied in populations at risk for sleep-disordered breathing or cardiovascular diseases. Taking into account improvements in recording techniques and new criteria used to define respiratory events, we aimed to assess the prevalence of sleep-disordered breathing and associated clinical features in a large population-based sample.

Methods—Between Sept 1, 2009, and June 30, 2013, we did a population-based study (HypnoLaus) in Lausanne, Switzerland. We invited a cohort of 3043 consecutive participants of the CoLaus/PsyCoLaus study to take part. Polysomnography data from 2121 people were included in the final analysis. 1024 (48%) participants were men, with a median age of 57 years (IQR 49–68, range 40–85) and mean body-mass index (BMI) of 25·6 kg/m^2 (SD 4·1). Participants underwent complete polysomnographic recordings at home and had extensive phenotyping for diabetes, hypertension, metabolic syndrome, and depression. The primary outcome was prevalence of sleep-disordered breathing, assessed by the apnoea-hypopnoea index.

Findings—The median apnoea-hypopnoea index was 6·9 events per h (IQR 2·7–14·1) in women and 14·9 per h (7·2–27·1) in men. The prevalence of moderate-to-severe sleep-disordered breathing (≥15 events per h) was 23·4% (95% CI 20·9–26·0) in women and 49·7% (46·6–52·8) in

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Contributors RH and MT designed the HypnoLaus study and are co-principal investigators. NT and DA recruited participants and did the sleep studies. DA, NT, JH-R, and RH analysed the sleep studies. PV, PM-V, MP, VM, and GW provided cardiovascular and metabolic data from the main cohort (CoLaus). PM-V, HM-S, and RH did the statistical analysis. RH, JH-R, and AM analysed and interpreted sleep, cardiovascular, and metabolic data. RH, SV, and JH-R wrote the report. All authors critically reviewed the report.

Declaration of interests

We declare no competing interests.

men. After multivariable adjustment, the upper quartile for the apnoea-hypopnoea index (>20·6 events per h) was associated independently with the presence of hypertension (odds ratio 1·60, 95% CI 1·14–2·26; p=0·0292 for trend across severity quartiles), diabetes (2·00, 1·05–3·99; p=0·0467), metabolic syndrome (2·80, 1·86–4·29; p<0·0001), and depression (1·92, 1·01–3·64; p=0·0292).

Interpretation—The high prevalence of sleep-disordered breathing recorded in our population-based sample might be attributable to the increased sensitivity of current recording techniques and scoring criteria. These results suggest that sleep-disordered breathing is highly prevalent, with important public health outcomes, and that the definition of the disorder should be revised.

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Introduction

Sleep-disordered breathing is a chronic disorder caused by repeated upper-airway collapse during sleep, resulting in recurrent nocturnal asphyxia, fragmented sleep, major fluctuations in blood pressure, and increased sympathetic nervous system activity.[1] Furthermore, patients with untreated sleep-disordered breathing are at increased risk of hypertension, stroke, heart failure, diabetes, car accidents, and depression.[2–9] Polysomnography is the gold standard to diagnose sleep-disordered breathing. However, despite the important effect of sleep-disordered breathing on public health, only a few attempts have been made to screen the general population for this disorder using polysomnography. In the late 1980s and early 1990s, three large cohort studies were done in the USA: the Wisconsin Sleep Cohort Study,[10] the Sleep Heart Health Study,[11] and the Penn State Cohort.[12] From these studies, the prevalence of sleep-disordered breathing—defined by an apnoea-hypopnoea index greater than five events per h—was estimated to be between 6·5% and 9% in women and between 17% and 31% in men.[10,12] However, this prevalence has since been revised to around 34% in men aged 30–70 years and 17% in women aged 30–70 years.[13] Although these studies provide important epidemiological data, they included an enriched selection of people at risk for sleep-disordered breathing (based on questionnaires) or cardiovascular disease. Therefore, the prevalence of sleep-disordered breathing could not be measured directly but was estimated through complex statistical calculations with reference to other population-based studies.

Researchers on subsequent epidemiological studies have either selected specific ethnic groups[14,15] or high-risk populations.[16] To record nocturnal breathing, all except a few[13,17] used less sensitive technology (eg, pen and paper recorders, thermocouples, or respiratory inductive plethysmography)[16,18] than nasal pressure technology, which is now the standard of care. Furthermore, pulse oximeters have improved considerably over the years. Both technical developments have increased sensitivity for diagnosis of sleep-disordered breathing. Moreover, the American Academy of Sleep Medicine (AASM) has revised criteria used to define nocturnal respiratory events.[19–21] Because most clinical settings now use recording techniques with increased sensitivity and the new definitions for respiratory

events, the prevalence of sleep-disordered breathing and its association with important health outcomes needs to be revisited.

We designed the HypnoLaus Sleep Cohort study to assess the prevalence of sleep-disordered breathing using state-of-the-art polysomnographic recording techniques and updated definitions in a general unselected population. Furthermore, the clinical relevance of the revised definition of sleep-disordered breathing was also investigated by examining its associations with cardiovascular, metabolic, and psychiatric comorbidities.

Methods

Participants

We selected participants for our study from individuals included in the population-based CoLaus/PsyCoLaus cohort study, described previously.[22,23] Briefly, the CoLaus/PsyCoLaus study was undertaken between 2003 and 2006 and included a sample of 6733 people aged 35–75 years, who were selected at random (using Stata version 9.1) from the population register of the city of Lausanne, Switzerland (altitude approximately 490 m).[22] The distribution of age groups, sex, and postal codes in CoLaus/PsyCoLaus participants was representative of the source population.[22] The original aim of the CoLaus/PsyCoLaus cohort study was to investigate the prevalence of cardiovascular risk factors and psychiatric disorders in the general population and to identify genetic determinants and mechanisms involved in their association.

At 5-year follow-up of the CoLaus/PsyCoLaus cohort (in 2009–12), individuals who were willing to return underwent a second physical (n=5064) and psychiatric (n=4001) examination and were given questionnaires by trained interviewers. These assessments included questions on their demographic, medical, and treatment history, and smoking and alcohol consumption. Sleep-related complaints and habits were investigated using the Pittsburgh sleep quality index, the Epworth sleepiness scale, and the Berlin questionnaire for sleep-disordered breathing. Blood samples were taken in the fasting state and a large panel of biological variables was measured.[24] Selection of participants for the HypnoLaus Sleep Cohort study was consecutive and not based on responses to the questionnaires; investigators were unaware of the results of the questionnaires.

The ethics committee of the University of Lausanne approved the CoLaus/PsyCoLaus cohort study and the HypnoLaus Sleep Cohort study. We obtained written informed consent from all participants.

Procedures

Polysomnography was done by certified technicians to assess the prevalence of sleep-disordered breathing. They equipped participants with a polysomnographic recorder (Titanium, Embla Flaga, Reykjavik, Iceland) between 1700 h and 2000 h at the Center for Investigation and Research in Sleep at the University Hospital of Lausanne. All sleep recordings took place in the patients' home environment in accordance with 2007 AASM recommended setup specifications.[19] We recorded breathing using nasal pressure sensors.

We asked individuals who were currently receiving treatment for sleep-disordered breathing (n=38) to discontinue their treatment 1 week before the sleep recording.

Two trained sleep technicians (DA and NT) who were unaware of the results of the previous questionnaires scored polysomnographic recordings manually using Somnologica software (version 5.1.1, Embla Flaga, Reykjavik, Iceland). An expert sleep clinician (JH-R) reviewed every recording and a second sleep expert (RH) did random quality checks. Quality control for concordance between the two polysomnography scorers was implemented periodically to ensure that both technicians achieved at least 90% agreement for sleep stages and respiratory events and an 85% level of agreement for arousals.[25] We scored sleep stages and arousals according to 2007 AASM recommendations.[19] We defined apnoea as a drop of at least 90% of airflow from baseline lasting 10 s or longer. We initially scored hypopnoea events using 1999 AASM Chicago criteria,[20] but all recordings were rescored using the more restrictive 2007 AASM criteria[19] and the more liberal 2012 AASM criteria[21] (≥30% drop of airflow lasting at least 10 s with either an arousal or ≥3% oxygen saturation drop). We used the 2012 criteria for our analysis (because they are the most recent and currently recommended criteria) and reported the average number of apnoea and hypopnoea events per h of sleep (the apnoea-hypopnoea index). We defined sleep-disordered breathing with usual clinical thresholds (ie, no sleep-disordered breathing, <5 events per h; mild, ≥5 to <15 events per h; moderate, ≥15 to <30 events per h; and severe, ≥30 events per h). The appendix (p 4) shows apnoea-hypopnoea index scores using 1999 and 2007 criteria.[19,20] We defined excessive daytime sleepiness as an Epworth score greater than ten (maximum score 24).

We did various clinical tests before polysomnography to investigate the association of sleep-disordered breathing with cardiovascular, metabolic, and psychiatric comorbidities. We measured blood pressure three times on the left arm and calculated the average of the last two readings. We defined arterial hypertension as either systolic blood pressure of 140 mm Hg or higher, diastolic blood pressure of 90 mm Hg or higher, or current use of antihypertensive drugs. We calculated the waist-to-hip ratio as the ratio of the circumference of the waist to that of the hip, as recommended by WHO. We measured neck circumference between the mid-cervical spine and the mid-anterior neck, just below the laryngeal prominence, if palpable. We obtained a fasting blood sample for various analyses, including measurement of glucose concentration and lipids. We defined diabetes as either fasting blood glucose of 7 mmol/L or higher or current drug treatment for diabetes. We defined metabolic syndrome according to the Adult Treatment Panel III (ATP-III) report.[26] Participants self-reported their alcohol drinking habits and the number of alcoholic drinks taken during the evening preceding the polysomnographic recording. We used the semi-structured Diagnostic Interview for Genetic Studies to diagnose a current major depressive episode, which we defined according to criteria of the Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV).

See **Online** for appendix
For more on **R** see http://www.r-project.org/

Statistical analysis

We did all statistical analyses with Stata version 11 (College Station, TX, USA) and R. We summarised data as either the number of participants (% or 95% CI), mean (SD), and median (IQR). We did bivariate analyses with the χ^2 test, Student's *t* test, or Wilcoxon's rank-sum test. We used Cohen's *d* to calculate the effect size of the differences between participants who underwent polysomnography and those who did not. We used logistic regression models to assess the association between various demographic and clinical variables and both mild-to-severe sleep-disordered breathing (≥5 events per h on the apnoea-hypopnoea index) and moderate-to-severe sleep-disordered breathing (≥15 per h on the apnoea-hypopnoea index), in men and women. To estimate the association between severity of sleep-disordered breathing and risk of diabetes, hypertension, metabolic syndrome, and depression, we used logistic regression models and divided our sample into quartiles of apnoea-hypopnoea index (Q1, 0–4·2 events per h; Q2, 4·3–9·9 events per h; Q3, 10·0–20·6 per h; Q4, >20·6 events per h). We compared models with the likelihood ratio test.

Role of the funding sources

The Faculty of Biology and Medicine of Lausanne, the Lausanne University Hospital (CHUV), Leenaards Foundation, and Ligue Pulmonaire Vaudoise funded the salary of the technicians who did the sleep recordings. The Swiss National Science Foundation funded the statisticians and supported the initial CoLaus cohort. GlaxoSmithKline supported the initial CoLaus cohort and funded the polysomnography recorders. The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all data in the study and had final responsibility for the decision to submit for publication.

Results

Between Sept 1, 2009, and June 30, 2013, a consecutive sample of 3043 people from the CoLaus/PsyCoLaus study cohort were invited to undergo polysomnography overnight at their home (appendix p 1). Of these, 2168 (71%) individuals accepted the invitation and underwent polysomnography. Of the 2168 polysomnographic recordings, 60 (3%) had technical problems resulting in insufficient data; 54 participants underwent a second recording and six people declined. 41 individuals with a total sleep time less than 4 h were excluded because of the risk of an unbalanced representation of different sleep stages and positions; therefore, 2121 polysomno-graphic recordings were included in the analysis, and these people comprised the HypnoLaus cohort. Table 1 presents demographic and clinical characterisitics of the study cohort.

Compared with the whole CoLaus/PsyCoLaus cohort, individuals who underwent polysomnography were similar in terms of age, sex, body-mass index (BMI), and ethnic origin, and they were representative of Lausanne's general population.[22] However, some mild differences were noted between the two cohorts with respect to scores on the Pittsburgh sleep quality index, the Epworth sleepiness scale, and the Berlin questionnaire for sleep-disordered breathing (appendix p 3).

In the total HypnoLaus Study cohort, hypopnoea was the most common respiratory event (75%), followed by obstructive sleep apnoea (19%), central apnoea (4%), and mixed apnoea (2%). To assess a possible first-night effect, the first 20 participants underwent two consecutive polysomnographic recordings at home. The type and severity of respiratory events and sleep quality were similar between the two nights (data not shown).

Figure 1 shows the prevalence of sleep-disordered breathing according to clinically defined categories (mild, moderate, and severe) in men and women. An apnoea-hypopnoea index of five or more events per h (ie, mild-to-severe sleep-disordered breathing) was recorded in 858 (83·8%; 95% CI 81·4–86·0) men and 667 (60·8%; 57·8–63·7) women, whereas an apnoea-hypopnoea index of 15 or more events per h (moderate-to-severe sleep-disordered breathing) was noted in 509 (49·7%; 46·6–52·8) men and 257 (23·4%; 20·9–26·0) women. To assess the effect of age on prevalence of sleep-disordered breathing, we divided our population into two age categories, younger than 60 years and 60 years or older, which is roughly the median age of the total participants. Moderate-to-severe sleep-disordered breathing increased significantly in older participants compared with those in the younger age group, but this difference in prevalence seems to be less important for sleep apnoea syndrome (figure 1).

The main risk factors associated with presence of sleep-disordered breathing were sex, age, BMI, neck circumference, waist-to-hip ratio (in women), and snoring (table 2). However, no association was noted between severity of sleep-disordered breathing and presence of daytime sleepiness, measured with the Epworth sleepiness scale.

Compared with women, scores on the apnoea-hypopnoea index were around three times higher in men in the younger age category (≥40 to <60 years) and twice as high in older men (≥60 years; table 3). 305 (49%) women younger than 60 years were postmenopausal, and this number rose to 490 (100%) in those 60 years or older. Median scores on the apnoea-hypopnoea index were significantly lower in premenopausal women (2·8 [IQR 1·5–7·5] events per h) compared with postmenopausal women (8·7 [4·2–16·9]; p<0·0001). Compared with men with moderate-to-severe sleep-disordered breathing, women in this category were older (67 years [IQR 57–73] *vs* 62 years [53–70]; p<0·0001) and had a lower Epworth score (mean 5·6 [SD 3·6] *vs* 6·6 [3·8]; p=0·0005). Men and women in the moderate-to-severe category had similar BMI (mean 27·6 kg/m^2 [SD 5·1] *vs* 27·2 kg/m^2 [3·7], p=0·24), but women had a smaller neck circumference (mean 35·3 cm [SD 2·6] *vs* 40·6 cm [2·8]; p<0·0001) and a lower waist-to-hip ratio (mean 0·90 [SD 0·06] *vs* 0·97 [0·05]; p<0·0001).

Figure 2 shows the association between severity of sleep-disordered breathing and risk of diabetes, hypertension, metabolic syndrome, and depression using four models with progressive adjustments. Adjusting for BMI (in model 3) significantly decreased the associations between sleep-disordered breathing and diabetes, hypertension, and metabolic syndrome. Conversely, adjusting for age and sex revealed an association between depression and sleep-disordered breathing in model 2. In the fully adjusted models (model 4), the upper quartile of the apnoea-hypopnoea index (Q4, >20·6 events per h) was associated independently with the presence of hypertension (odds ratio 1·60, 95% CI 1·14–2·26; p=0·0292 for trend across severity quartiles), diabetes (2·00, 1·05–3·99; p=0·0467),

metabolic syndrome (2·80, 1·86–4·29; p<0·0001), and depression (1·92, 1·01–3·64; p=0·0292). The interaction term BMI × apnoea-hypopnoea index for hypertension (p=0·875), diabetes (p=0·490), and metabolic syndrome (p=0·382) was not included in these models because they were not significant. Using the apnoea-hypopnoea index as a continuous variable in the same fully adjusted regression models led to similar independent associations with diabetes (p=0·0119), metabolic syndrome (p<0·0001), hypertension (p=0·0098), and depression (p=0·0260).

Discussion

To our knowledge, the HypnoLaus Sleep Cohort study is the largest study to assess the prevalence of sleep-disordered breathing in a population-based sample using the most recent polysomnographic recording techniques and scoring criteria. We recorded a much higher than previously estimated prevalence of sleep-disordered breathing and an independent association between the disorder and diabetes, hypertension, metabolic syndrome, and depression, albeit mainly in the highest severity quartile of the apnoea-hypopnoea index (>20·6 events per h).

The first report of prevalence of sleep-disordered breathing was published 20 years ago by Young and colleagues[10] and was based on the Wisconsin Cohort Study (WSCS). In a follow-up of WSCS, increased prevalence estimates were reported.[13] However, the earlier study was not strictly population-based because it included an enriched selection of people at risk for sleep-disordered breathing (panel). The reported prevalence of sleep-disordered breathing was, thus, estimated using models extrapolating the observed results to the general US population using demographic data from the National Health and Nutrition Examination Survey (NHANES) study.

The high prevalence of sleep-disordered breathing recorded in our cohort could be accounted for by two factors. First, we measured the prevalence of sleep-disordered breathing directly in the general population rather than estimating it; and second, we used currently recommended techniques (including nasal pressure sensors) and scoring criteria. To date, only two studies based directly on samples from the general population have been done.[17,18] In both studies, researchers reported a high prevalence of sleep-disordered breathing. In a study from Spain of 2148 individuals aged 30–70 years,[18] the prevalence of sleep-disordered breathing (apnoea-hypopnoea index >5 events per h) was 26·2% in men and 28·0% in women. However, full polysomnography was only used in a subset of 390 participants, and most participants were studied with limited channels recorders without direct airflow measurement, which does not match current standards.[21] In a study from Brazil of 1042 participants aged 20–80 years,[17] the latest breathing sensors were used to measure variation in nasal pressure (which is the technique currently used in all modern clinical laboratories). The researchers reported a high prevalence of sleep-disordered breathing (apnoea-hypopnoea index >5 events per h) of 46·6% in men and 30·5% in women; however, these results were obtained in a specific mixed ethnic population and are difficult to generalise to other populations.

The findings of these studies and ours suggest that the prevalence of sleep-disordered breathing is highly dependent on technical factors. Nasal pressure sensors detect subtle breathing variations, resulting in detection of more hypopnoea events (and, therefore, a higher apnoea-hypopnoea index) than with thermistors, which have decreased sensitivity (appendix p 2).[27,28] The 2012 AASM criteria[21] propose a more liberal definition of hypopnoea, whereas more strict definitions were used in previous studies. Although this change in definition might partly account for the increased prevalence of sleep-disordered breathing in our study, prevalence was still higher than previously reported after rescoring the polysomnographic recordings using the older and more restrictive criteria (appendix p 4).

In our study, clinical and epidemiological factors associated with sleep-disordered breathing were increasing age, male sex, large neck circum ference, obesity, and reported snoring, similar to previous studies.[10,12,29] The difference in prevalence of sleep-disordered breathing between men and women seemed to diminish in participants aged 60 years or older, probably because of the increased proportion of postmenopausal women in this age category, who had a higher median apnoea-hypopnoea index compared with premenopausal women. Even though women and men with an apnoea-hypopnoea index of 15 or more events per h had a similar BMI, women had a lower neck circumference and waist-to-hip ratio compared with men. This finding confirms that not only central obesity but also hormonal status affects the prevalence of sleep-disordered breathing in women.

Independent associations between severity of sleep-disordered breathing and diabetes, hypertension, metabolic syndrome, and depression were noted after multivariable adjustment. This finding suggests that we identified a clinically important disease rather than simply over-diagnosing healthy individuals. These results accord with findings of the WSCS,[2] in which sleep-disordered breathing was associated prospectively with hypertension, a result confirmed by later observational and interventional studies.[30,31] Moreover, a prospective association with depression has been reported previously.[8] Diabetes seems to have a bidirectional association with sleep-disordered breathing: intermittent hypoxaemia contributes to development of insulin resistance and glucose intolerance, and type 2 diabetes increases an individual's predisposition to sleep-disordered breathing.[9,32,33] However, fewer reports have been published of an association between sleep-disordered breathing and metabolic syndrome.[34]

In previous studies, even sleep-disordered breathing of the lowest severity (apnoea-hypopnoea index >5 events per h) was associated with hypertension[2,18] or depression.[8] However, we noted these associations mostly in the upper quartile of severity (apnoea-hypopnoea index >20·6 events per h). Since current recording techniques and scoring criteria are more sensitive than those used previously, this finding strongly suggests that the definition of sleep-disordered breathing should be revised. Indeed, in our study, almost every individual had some degree of sleep-disordered breathing, and an increasing apnoea-hypopnoea index was associated with augmented prevalence of comorbid diseases. These results reinforce the idea that, instead of using the arbitrary diagnostic threshold of the apnoea-hypopnoea index, sleep-disordered breathing should be considered as a disease characterised by a severity spectrum, akin to blood pressure or cholesterol levels. Treatment

of sleep-disordered breathing should, thus, be increasingly aggressive with rising apnoea-hypopnoea index, particularly in individuals with risk factors for comorbidities associated with sleep-disordered breathing, such as sleepiness, cardiovascular disease, metabolic disease, and depression. Treatments will ultimately be guided by appropriately designed clinical trials, but individuals with a low apnoea-hypopnoea index and at low risk for comorbidities could be treated conservatively to reduce risk factors for sleep-disordered breathing (eg, weight control or avoiding sleep in the supine position), whereas individuals at higher risk could benefit from continuous positive airway pressure (CPAP), mandibular advancement devices, and surgery (eg, maxillomandibular advancement surgery) in selected cases. This rational approach to sleep-disordered breathing is implemented de facto by skilled clinicians; however, our results emphasise the importance of dedicating health care resources to individuals at high risk of complications rather than initiating treatment based on an apnoea-hypopnoea index threshold. Ultimately, follow-up of the HypnoLaus cohort will allow us to identify individuals at high risk of incident complications (eg, using biological or genetic markers) and will help to provide therapeutic recommendations in an individualised manner.

The major strengths of our study are that it was done in a large, population-based sample, enabling extrapolation of findings to the original population. Moreover, poly somnographic recordings were done in the participant's home environment, thus minimising the likelihood of information bias. Finally, modern recording techniques and scoring criteria were applied, which ensures validity of results in view of current recommendations.[21]

The main limitations of our study are the cross-sectional setting and the inclusion of individuals aged 40–85 years old only, almost exclusively of white European origin and with a low prevalence of obesity. Thus, generalisation of findings to younger people, to populations with a high prevalence of obesity, or to people from other ethnic backgrounds is limited. For example, the average BMI is lower in Switzerland than in the USA, suggesting that the prevalence of sleep-disordered breathing could be higher in a North American population. Second, 29% of participants declined to have polysomnography, which might have caused selection bias. However, since the HypnoLaus sample was similar in terms of age, sex, BMI, and ethnic origin to the CoLaus/PsyCoLaus cohort, which is representative of Lausanne's general population, we believe that our results are probably very close to the true prevalence of sleep-disordered breathing in the general population. Finally, a variable time gap existed between clinical assessment of participants and polysomnography, but it probably did not affect the association between severity of sleep-disordered breathing and diabetes, hypertension, metabolic syndrome, and depression, since these disorders are typically chronic conditions.

The prevalence of sleep-disordered breathing in the general population is considerably higher than previously reported when the most recent recording techniques and scoring criteria are used. Caution is thus needed when comparing the prevalence of sleep-disordered breathing with previous studies in which different sampling frames, recording techniques, and scoring criteria were used. These results, and the progressive association between severity of sleep-disordered breathing and cardiovascular, metabolic, and psychiatric

diseases, suggest that an arbitrary threshold for the apnoea-hypopnoea index could be hard to define and clinical decisions might need a complete clinical picture to be well informed.

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Panel: Research in context

Systematic review

We searched PubMed up to October, 2014, with the terms “sleep apnea”, “sleep apnoea”, or “sleep disordered breathing”, and “prevalence”. After exclusion of studies that did not include objective nocturnal measurements, we retrieved 21 epidemiological studies assessing the prevalence of sleep-disordered breathing in different populations. Results of epidemiological studies done in the late 1980s and 1990s showed a rather low prevalence of sleep-disordered breathing, probably due to low sensitivity of recording techniques.[10,12] These and almost all subsequent studies included population samples selected or enriched with individuals presenting risk factors for sleep-disordered breathing or cardiovascular disease, and were thus not representative of the general population. Therefore, statistical corrections were needed to estimate the prevalence of sleep-disordered breathing in the general population in those studies. Another important factor affecting prevalence of sleep-disordered breathing is the definition of respiratory events, which strongly affects the apnoea-hypopnoea index (appendix p 4). Since these definitions were updated in 2012, none of the previous epidemiological studies could use the up-to-date definition of respiratory events.

Interpretation

Using the most recent definitions for respiratory events, and diagnostic techniques commonly used in all modern sleep laboratories, we noted that almost every individual had some degree of sleep-disordered breathing. Moreover, an increasing number of apnoea and hypopnoea events per h was associated with augmented comorbidity. This finding reinforces the idea that sleep-disordered breathing should be considered as a disease with a continuous spectrum, rather than as a definite yes or no diagnosis. Individuals at high risk of incident sleep-disordered breathing-related complications should be identified so treatment efforts can be focused on them.

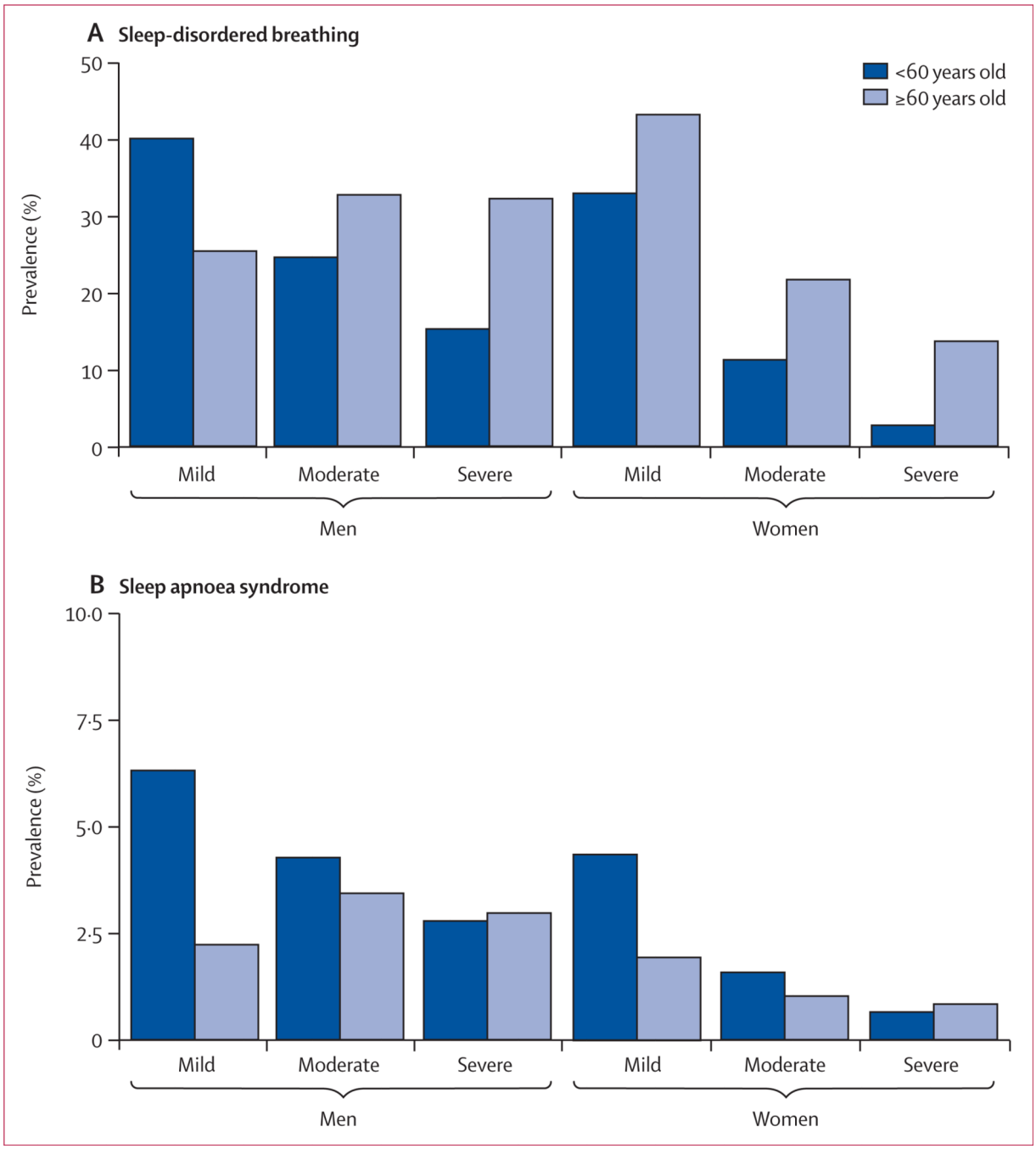

Figure 1. Prevalence of sleep-disordered breathing and sleep apnoea syndrome, according to age and sex

(A) Mild sleep-disordered breathing was defined as ≥5 to <15 events per h, moderate was ≥15 to <30 events per h, and severe was ≥30 events per h. Sleep-disordered breathing categories differed by age; p<0·0001 in men and p<0·0001 in women. (B) Mild sleep apnoea syndrome was defined as ≥5 to <15 events per h and an Epworth score >10, moderate was ≥15 to <30 events per h and an Epworth score >10, and severe was ≥30 events per h and an Epworth score >10. Categories of sleep apnoea syndrome differed by age; p<0·0001 in men and p<0·0001 in women.

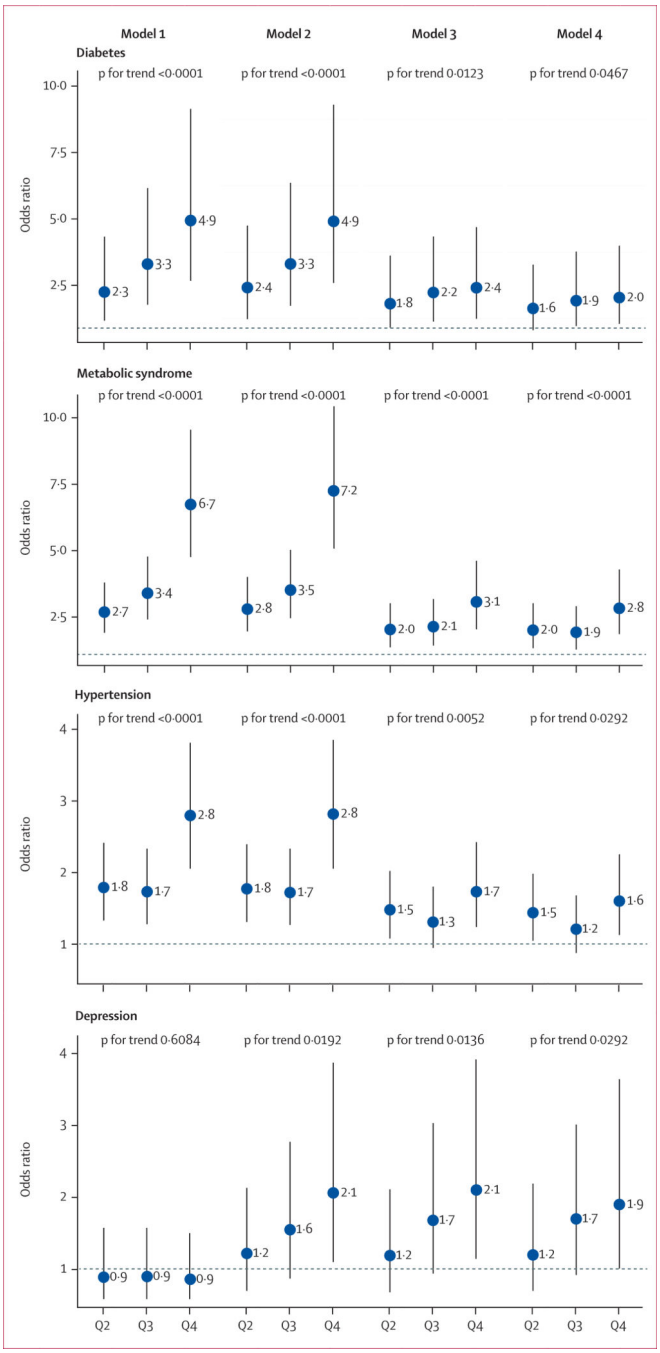

Figure 2. Estimated risk for diabetes, metabolic syndrome, hypertension, and depression associated with severity of sleep-disordered breathing

Circles represent the odds ratio and bars the 95% CI. If bars cross the dotted line at 1·0, risk is not significant. Apnoea-hypopnoea index severity quartiles are defined as: Q1, 0–4·2 events per h; Q2, 4·3–9·9 events per h; Q3, 10·0–20·6 events per h; and Q4, >20·6 events per h. p values are for trend across severity quartiles. For diabetes, metabolic syndrome, and hypertension: model 1 was adjusted for age and sex; model 2 was adjusted for age, sex, and alcohol and tobacco consumption; model 3 was adjusted for age, sex, alcohol and tobacco consumption, and BMI; and model 4 was adjusted for age, sex, alcohol and tobacco

consumption, BMI, neck circumference, and waist-to-hip ratio (except for metabolic syndrome because this ratio is part of its definition). For depression: model 1 was raw data; model 2 was adjusted for age and sex; model 3 was adjusted for age, sex, and use of benzodiazepines; and model 4 was adjusted for age, sex, use of benzodiazepines, and use of antidepressant drugs.

Table 1

Demographic and clinical characteristics of participants

	Total (n=2121)	Men (n=1024)	Women (n=1097)	p value*
Age (years)	57 (49–68)	56 (49–67)	58 (50–69)	0·0263
≥40 to <60	1219 (57%)	613 (60%)	606 (55%)	..
≥60	902 (43%)	411 (40%)	491 (45%)	..
BMI (kg/m^2)	25·6 (4·1)	26·2 (3·7)	25·1 (4·6)	<0·0001
Neck circumference (cm)	36·9 (3·9)	39·8 (2·8)	34·1 (2·4)	<0·0001
Waist-to-hip ratio	0·92 (0·07)	0·96 (0·06)	0·88 (0·06)	<0·0001
Alcohol use	560 (26%)	325 (32%)	235 (21%)	<0·0001
Smoking	1210 (57%)	654 (64%)	556 (51%)	<0·0001
Snoring	1164 (55%)	678 (66%)	486 (44%)	<0·0001
Hypertension	877 (41%)	497 (49%)	380 (35%)	<0·0001
Diabetes	212 (10%)	145 (14·%)	67 (6%)	<0·0001
Metabolic syndrome	641 (30%)	366 (36%)	275 (25%)	<0·0001
Epworth score	6 (3–9)	6 (4–9)	5 (3–8)	<0·0001
>10	258 (12%)	143 (14%)	115 (10%)	0·0129
PSQI score	4 (3–7)	4 (3–6)	5 (3–7)	<0·0001
Berlin score ≥2	525 (25%)	315 (31%)	210 (19%)	<0·0001

Data are number of participants (%), median (IQR), or mean (SD). BMI=body-mass index. PSQI=Pittsburgh sleep quality index.

*Comparison between men and women.

Table 2

Risk of sleep-disordered breathing according to related factors, by severity

	Men				Women			
	Mild-to-severe	**p value**	**Moderate-to-severe**	**p value**	**Mild-to-severe**	**p value**	**Moderate-to-severe**	**p value**
Age (per 10-year increment)	1·32 (1·13–1·52)	0·0008	1·53 (1·38–1·68)	<0·0001	1·72 (1·53–1·90)	<0·0001	1·72 (1·50–1·94)	<0·0001
BMI (kg/m^2)								
25–30 (*vs* <25)	1·82 (1·13–2·91)	0·0132	1·74 (1·16–2·59)	0·0058	3·25 (2·12–4·97)	<0·0001	1·90 (1·16–3·12)	0·0110
>30 (*vs* <25)	4·18 (1·50–11·7)	0·0062	2·84 (1·51–5·34)	0·0012	2·43 (1·23–4·82)	0·0110	1·75 (0·87–3·54)	0·1171
Neck circumference (per 1 cm increment)	1·02 (0·93–1·13)	0·6296	1·11 (1·03–1·20)	0·0044	1·07 (0·97–1·17)	0·1685	1·14 (1·03–1·26)	0·0135
Waist-to-hip ratio (per quartile increment)*								
Quartile 2 (*vs* quartile 1)	1·16 (0·72–1·86)	0·5376	1·35 (0·88–2·06)	0·4681	1·47 (0·93–2·32)	0·0951	1·27 (0·67–2·39)	0·4657
Quartile 3 (*vs* quartile 1)	1·54 (0·86–2·78)	0·1490	1·22 (0·77–1·93)	0·4017	1·72 (1·10–2·69)	0·0176	1·86 (1·04–3·34)	0·0376
Quartile 4 (*vs* quartile 1)	1·82 (0·94–3·50)	0·0738	1·47 (0·92–2·37)	0·1098	1·76 (1·02–3·04)	0·0406	1·85 (0·98–3·52)	0·0595
Alcohol use (yes *vs* no)†	0·86 (0·57–1·29)	0·4550	1·02 (0·74–1·41)	0·8969	0·75 (0·50–1·13)	0·1647	0·84 (0·51–1·40)	0·5092
Epworth (>10 *vs* ≤10)	1·02 (0·97–1·07)	0·5367	1·01 (0·97–1·05)	0·6826	0·98 (0·93–1·02)	0·3451	0·99 (0·94–1·05)	0·8542
Snoring (yes *vs* no)	1·67 (1·09–2·57)	0·0187	2·29 (1·55–3·38)	<0·0001	2·34 (1·63–3·36)	0·0001	3·39 (2·07–5·54)	<0·0001
Berlin score (≥2 *vs*<2)	1·31 (0·79–2·17)	0·2964	1·25 (0·87–1·79)	0·2319	1·64 (0·99–2·71)	0·0531	1·69 (1·05–2·70)	0·0300

Mild-to-severe sleep-disordered breathing was defined as an apnoea-hypopnoea index of five or more events per h. Moderate-to-severe sleep-disordered breathing was defined as an apnoea-hypopnoea index of 15 or more events per h. Statistical analysis by logistic regression models. BMI=body-mass index.

*For men: quartile 1, <0·93; quartile 2, 0·93–0·96; quartile 3, 0·97–0·99; quartile 4, >0·99. For women: quartile 1, <0·85; quartile 2, 0·85–0·88; quartile 3, 0·89–0·93; quartile 4, >0·93.

†During the evening before polysomnography.

Table 3

Scores on the apnoea-hypopnoea index and oxygen desaturation index, by sex and age

	Total	Men	Women	p value*
Apnoea-hypopnoea index (events per h)				
Total	9·9 (4·2–20·6)	14·9 (7·2–27·1)	6·9 (2·7–14·1)	<0·0001
Age ≥40 to <60 years	7·6 (2·9–15·9)	11·7 (6·1–21·1)	4·3 (1·9–9·3)	<0·0001
Age ≥60 years	14·3 (7·0–27·2)	21·1 (9·4–35·6)	10·8 (5·5–20·0)	<0·0001
p value†	<0·0001	<0·0001	<0·0001	..
3% oxygen desaturation index (events per h)				
Total	9·9 (4·3–19·4)	14·4 (6·9–24·9)	6·9 (2·9–13·5)	<0·0001
Age ≥40 to <60 years	7·3 (3·2–15·0)	11·4 (5·9–20·0)	4·4 (1·9–9·3)	<0·0001
Age ≥60 years	13·8 (7·0–26·1)	19·5 (9·9–32·8)	11·0 (5·4–19·5)	<0·0001
p value†	<0·0001	<0·0001	<0·0001	..
4% oxygen desaturation index (events per h)				
Total	4·0 (1·2–10·1)	6·4 (2·3–14·25)	2·4 (0·7–6·5)	<0·0001
Age ≥40 to <60 years	2·7 (0·7–6·9)	4·7 (1·6–10·6)	1·3 (0·3–3·9)	<0·0001
Age ≥60 years	6·6 (2·5–15·6)	9·9 (3·9–21·1)	4·9 (1·9–10·3)	<0·0001
p value†	<0·0001	<0·0001	<0·0001	..

Data are median scores (IQR). The apnoea-hypopnoea index is defined as the number of apnoea and hypopnoea events per h. The oxygen desaturation index is defined as the number of 3% or 4% drops in oxygen saturation per h of sleep. p values calculated by Wilcoxon's rank-sum tests.

*Comparison between men and women.

†Comparison between age groups.