ERJ open research
THE BEST IN OPEN ACCESS BASIC, TRANSLATIONAL & CLINICAL RESPIRATORY RESEARCH

Early View

Original Research Article

Multimorbidity patterns in elderly sleep-disordered breathing patients

Jeppe Suusgaard, Christine Benn Christiansen, Morten Kjøbek Lambert, Mads Hashiba, Michael Ibsen, Rikke Ibsen, Jakob Kjellberg, Poul J. Jennum

Please cite this article as: Suusgaard J, Christiansen CB, Lambert MK, *et al*. Multimorbidity patterns in elderly sleep-disordered breathing patients. *ERJ Open Res* 2025; in press (https://doi.org/10.1183/23120541.00721-2025).

This manuscript has recently been accepted for publication in the *ERJ Open Research*. It is published here in its accepted form prior to copyediting and typesetting by our production team. After these production processes are complete and the authors have approved the resulting proofs, the article will move to the latest issue of the ERJOR online.

Copyright ©The authors 2025. This version is distributed under the terms of the Creative Commons Attribution Non-Commercial Licence 4.0. For commercial reproduction rights and permissions contact permissions@ersnet.org

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Multimorbidity patterns in elderly sleep-disordered breathing patients

Jeppe Suusgaard MD[1,2], Christine Benn Christiansen MD PhD[3,4], Morten Kjøbek Lambert MD PhD[5,8], Mads Hashiba[5], Michael Ibsen[6], Rikke Ibsen[6], Jakob Kjellberg[7], Poul J. Jennum MD DMSc [1,8]

1 Danish Center for Sleep Medicine, Department of Clinical Neurophysiology, Copenhagen University Hospital, Rigshospitalet, Denmark

2 Department of Brain and Spinal Cord Injury, Copenhagen University Hospital, Rigshospitalet, Denmark

3 Department of Neurology, Bispebjerg Hospital, Denmark

4 Department of Cardiology, Nordsjaellands Hospital, Hilleroed

5 Department of Cardiology, Copenhagen University Hospital – Herlev and Gentofte, Denmark

6 i2minds, Nørrebrogade 18b, Aarhus, Denmark.

7 Danish Institute for Local and Regional Government Research, Copenhagen, Denmark.

8 Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark

Corresponding Author:

Jeppe Suusgaard, MD, Danish Center for Sleep Medicine, Rigshospitalet; Valdemar Hansens vej 1, 2600 Glostrup, Denmark; jeppe.suusgaard.kjoelhede@regionh.dk, +45 23 74 45 50.

Summary:

In adults ≥65, sleep-disordered breathing (SDB) was linked to 3x higher odds of multimorbidity and increased mortality. Strongest associations were with cardiovascular and metabolic diseases, highlighting the broad health impact of SDB in older patients.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Abstract

Background:

Multimorbidity (≥2 chronic diseases) is common among older adults and is linked to increased disability and mortality. Sleep-disordered breathing (SDB) is underdiagnosed and has been associated with several chronic diseases. However, little is known about the specific patterns of comorbidity in the elderly. This study investigated the association between SDB and multimorbidity patterns in individuals aged ≥65 years and assessed the impact of SDB on all-cause mortality.

Methods:

This registry-based case-control study utilized the Danish National Patient Registries from 2002 to 2019. Individuals aged ≥65 years diagnosed with SDB were identified and matched 1:4 with controls based on age, sex, cohabitation status, and region of residence. Comorbidities were categorized using eight WHO disease chapters, and 22 specific chronic diseases were assessed within seven years prior to SDB diagnosis. Conditional logistic regression estimated odds ratios (ORs) for comorbidities; Cox hazard regression models evaluated mortality risk.

Results:

A total of 21,555 patients with SDB were matched to 86,212 controls. Patients with SDB had significantly higher odds of multimorbidity (OR 2.99, $p < 0.01$), with increased prevalence across all eight WHO disease groups. The highest ORs were found in the cardiovascular (OR 2.52, $p < 0.01$) and metabolic disease categories (OR 2.52, $p < 0.01$). SDB was associated with elevated all-cause mortality (hazard ratio 1.09, $p < 0.01$).

Conclusion:

SDB in older adults is associated with multimorbidity and increased mortality, highlighting the need for increased recognition and coordinated treatment of SDB in elderly patients with multiple chronic conditions.

Keywords

Elderly, mortality, multimorbidity, sleep apnea, sleep-disordered breathing.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Introduction

Obstructive sleep apnea (OSA) is the most common form of sleep-disordered breathing (SDB) and is a highly prevalent but underrecognized condition in older adults(1,2). Characterized by recurrent episodes of upper airway obstruction during sleep, OSA leads to intermittent hypoxia, sleep fragmentation, and systemic inflammation with increased levels of inflammatory markers (e.g., VEGF, CRP, IL-6, and TNFα) (3–7). Through these mechanisms, the clinical consequences of OSA extend beyond poor sleep quality, by increasing the risks for cardiovascular events, stroke, extended hospitalization, and mortality(6,8–12). Recent research suggests that OSA may act as a contributor within multimorbidity patterns, not only coexisting with chronic diseases, but also exacerbate their development and progression(13–15).

In patients with multiple chronic diseases, a clear distinction between comorbidity and multimorbidity is important. Comorbidity refers to the presence of additional conditions relative to an index disease, where multimorbidity refers to the coexistence of two or more chronic diseases without prioritizing one (16). This distinction is particularly relevant in older adults, where co-occurring chronic diseases are common. A disease-centered approach may overlook potential interactions among coexisting diseases, leading to both incomplete clinical assessments and treatment strategies(16). In the context of personalized medicine and increasing life expectancy, understanding the full spectrum of disease burden in elderly patients with OSA is essential to inform targeted therapeutic strategies and improve clinical outcomes(17–19).

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Despite these considerations, large-scale, longitudinal data describing multimorbidity patterns and mortality in elderly adults with OSA are limited(13,20). There is a need for population-level insights into how OSA influences the structure and evolution of multimorbidity. In this nationwide registry-based study, we aimed to characterize the comorbidity burden in individuals aged ≥ 65 years with SDB and evaluate the association between SDB and all-cause mortality.

Methods

This is a register-based case-control study that utilized data from several Danish national registries. The primary data sources included the Danish National Patient Register (DNPR), the Danish National Prescription Register, and Statistics Denmark, which provided longitudinal socio-demographic information regarding education, income, employment status, immigration/emigration, use of medication, and mortality. Diagnostic data were classified using internationally recognized coding systems, primarily the International Classification of Diseases, 10th Revision (ICD-10).

Since the DNPR includes all in-patient and outpatient hospital contacts across Denmark, the data extracted are representative of all patients who were diagnosed with SDB. The availability of registry data varies by source, but complete data from all relevant registries were available for the period 1995–2021.

Study population

All patients in the DNPR with a hospital contact associated with an SDB diagnosis between 1995 and 2021 were identified. However, as consistent recording of SDB diagnoses began in 2002, the final inclusion period was restricted to patients diagnosed between 2002 and 2019 to ensure accurate capture and allow for a minimum two-year follow-up. To ensure inclusion of incident

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

cases the period back to 1994 was used as washout. Patients under 65 years at index were excluded. SDB is used throughout the manuscript to reflect registry-based diagnoses, which do not differentiate between subtypes such as OSA, central sleep apnea, or mixed forms.

During the study period, routine screening for SDB was not standard practice but based on physician referral. OSA was diagnosed using the American Academy of Sleep Medicine (AASM) criteria with updated hypopnea definitions applied from 2012 (Supplementary Table S1)(21,22). Diagnostic methods included home sleep apnea testing (HSAT), respiratory polygraphy, and polysomnography (PSG). Physicians were assumed to adhere to national diagnostic and treatment guidelines.

Each patient with SDB was randomly matched with controls in ratio of 1:4 based on age, sex, cohabiting status, and region of residence at the year of diagnosis (index year). The SAS SURVEYSELECT procedure was used to select the matched control group.

Variables and outcomes

Comorbidities were identified using ICD-10 diagnostic codes recorded in connection with any hospital contact (primary or secondary diagnosis) between January 1, 1995, and December 31, 2021. This provided a window of seven years prior to the index date for all participants. Comorbidities were aggregated according to eight WHO chapters of the ICD-10 classification system (e.g., Chapter 9: Diseases of the Circulatory System, I00–I99). Once a patient was identified with a diagnosis within a given WHO chapter, they were considered to have that comorbidity for all subsequent years. Comorbidity status at the index date reflects the cumulative presence of diagnoses during the 7-year pre-index period. Comorbidity aggregation was done in two stages: first, patients and controls were grouped into the relevant WHO chapters; second, these were further categorized into 22 major chronic disease groups. In certain cases, patients were identified

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

through prescription data using Anatomical Therapeutic Chemical (ATC) codes from the National Prescription Registry. The specific ICD-10 and ATC codes used and the rationale for disease group selection, are detailed in the supplementary materials (Supplementary Table S2). Mortality data, including date and cause of death (when applicable), were obtained from the National Death Registry.

Statistical analysis

Descriptive statistics were used to summarize sociodemographic and clinical characteristics. Categorical variables were summarized using frequencies and percentages, while continuous variables were reported as means and standard deviations. Group comparisons between patients and controls were conducted using Chi-square tests, t-tests, or Mann–Whitney U tests, as appropriate. Conditional logistic regression models were employed to assess associations between SDB and individual comorbidity categories. Results are presented as odds ratios (ORs) with corresponding 95% confidence intervals (CIs) and p-values. For survival analysis, Kaplan–Meier curves and Cox hazard regression models were used to compare all-cause mortality between patients and controls. Patients and controls were followed until death or were censored. Censoring criteria included emigration (censored at the date of emigration) or being alive at the end of the follow-up period.

Cox hazard models were adjusted for pre-existing comorbidities using the Quan adaptation of the Charlson Comorbidity Index (Quan-CCI), which includes 12 comorbidity categories predictive of in-hospital mortality(23). Only comorbidities documented within the three years prior to the SDB diagnosis were included in the mortality analysis . Hazard ratios (HRs), 95% CIs, and p-values are reported. Interaction analyses were conducted using logistic regression models for each comorbidity, comparing male and female patients to their respective controls. The dependent

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

variable was binary (0 = no comorbidity, 1 = presence of comorbidity). Models included main effects for case-control status, sex, and their interaction, which tested whether the association between SDB and comorbidity differed by sex. All statistical analyses were performed using SAS version 9.4 TS Level 1M5 (SAS Institute, Cary, NC, USA).

Results

Patient characteristics

We identified 21,555 patients who were diagnosed with SDB at age 65 or older between 2002 and 2019 (Figure 1). Patients were subsequently matched to 86,212 controls based on age, sex, region of residence, and cohabiting status. Baseline characteristics for both patients and matched controls are presented in Table 1. Compared to controls, the distribution of educational level and employment status differed significantly in patients with SDB (both $p < 0.01$). Descriptively, patients with SDB had slightly higher proportions of individuals with intermediate college-level education (14.5% vs. 13.3%) and vocational education (41.1% vs. 40.0%), and a slightly lower proportion of individuals who were employed (11.8% vs. 12.1%) compared to controls.

Multimorbidity and all-cause mortality

At the time of SDB diagnosis, patients exhibited a higher prevalence of multimorbidity compared to controls, both when considering all chronic diseases (81% vs. 59%, $p < 0.01$) and when focusing solely on somatic chronic diseases (77% vs. 56%, $p < 0.01$).

When comparing patients and controls applying conditional logistic regression models across eight WHO ICD-10 chapters, patients had higher odds of having a diagnosis in each category (Table 2). The most prevalent category was “Diseases of the Circulatory System (I00–I99)”, which also showed the highest odds of disease presence compared to controls (OR = 2.52, $p < 0.01$).

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Odds ratios (with 95% confidence intervals) for each disease category at -1 year and -7 years before SDB diagnosis are visualized in Figure 2. In all categories, the odds of having the condition increased steadily over time.

We extracted specific chronic diseases from the registries and applied the same logistic regression model across all conditions (Table 3). We observed increased odds for all 22 chronic diseases among patients compared with matched controls (Table 3). The highest odds were observed for "Other sleep disorders" (OR = 12.6, $p < 0.01$), which includes insomnia. This was followed by hypertension (OR = 2.7, $p < 0.01$), the most prevalent condition among both SDB patients (N = 1,787 ; 79.7%) and controls (N = 52,005 ; 60.3%).

Significant sex-specific differences were observed for several conditions (Table 4). Compared to their controls, males with SDB had lower odds of type 2 diabetes, movement disorders, and reflux or gastritis compared to their male controls, than did females with SDB relative to their female controls. Conversely, males with SDB had a significantly higher likelihood of being diagnosed with dyslipidemia and dementia or other cerebral disorders, relative to their controls, compared to females with SDB. For other conditions, including hypertension, atrial fibrillation, heart failure, thyroid disease, and obesity, no sex interactions were found.

Unadjusted survival curves for patients with SDB and controls are visualized in Figure 3. Cox hazard models were used to estimate the hazard ratio (HR) for all-cause mortality in patients with SDB versus matched controls (Table 5). The model showed that SDB was associated with increased mortality (HR 1.09 (95% CI [1.06 ; 1.13], $p < 0.01$). When adjusting for comorbidities, there was no difference in mortality between the SDB patients and controls (HR 1.02, 95% CI [0.99 ; 1.05], $p = 0.15$).

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Discussion

This study demonstrates that SDB in patients aged ≥ 65 years is associated with significantly higher odds of multimorbidity, increased disease burden across eight WHO categories, and higher odds for 22 chronic conditions prior to SDB diagnosis, compared to matched controls. Additionally, we observed increased mortality among SDB patients, likely driven by the number and severity of comorbid conditions. With over 21,000 elderly patients included across nearly two decades, this is one of the largest and most comprehensive studies, providing insights into the long-term health impact of SDB in elderly patients.

The relationship between SDB and the development of other chronic conditions have been widely theorized, with one hypothesis suggesting that SDB accelerates disease onset and progression within disease networks (15). Our findings support this theory, demonstrating increased odds of several chronic diseases before SDB diagnosis. This supports the concept of pathophysiological clustering, wherein SDB exacerbates other conditions through mechanisms such as systemic inflammation, sympathetic activation, and metabolic dysregulation (15).

One interpretation of our data is that the onset of SDB may be influenced by a pre-existing burden of chronic diseases, as odds of other diagnoses rose rapidly in the year before SDB diagnosis (Figure 2). An alternative explanation is that SDB may be detected only after patients enter structured diagnostic pathways for other conditions. This latter interpretation may be more plausible, especially in a healthcare context where SDB is often underdiagnosed.

While stroke and other conditions have been linked to later SDB development, our findings do not support a consistent temporal pattern (7,10). As this was an observational study, causal relationships cannot be established. Instead, the results emphasize the importance of recognizing

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

SDB as a clinically relevant and often coexisting condition within disease presentations in older adults.

Although some studies report lower cardiovascular risk in older adults, our findings and recent data indicate otherwise for those with SDB(24–26). In our study, patients had substantially higher rates of cardiovascular comorbidities than controls, consistent with other reports of rising cardiovascular mortality in older adults with SDB(25,27). Given the high prevalence of SDB among patients with resistant hypertension, heart failure, and pulmonary hypertension, older adults with untreated SDB appear to be a high-risk group that often remains undiagnosed and undertreated (28). This highlights the need for greater recognition and coordinated management of SDB within strategies addressing multimorbidity in elderly patients.

Some results, such as the increased odds of cancer in SDB patients (OR 1.20, 95% CI [1.16–1.24], $p < 0.01$), were more pronounced than anticipated. While previous studies have suggested a link between SDB and cancer, the topic remains controversial(29). It is possible that this association is influenced by selection bias or unmeasured confounding.

The age distribution revealed that 46% of the cohort was aged 65–69, which may partly explain the relatively high employment rate of 12% observed in both groups. This also reflects the functional heterogeneity of older adults, particularly in high-income countries with longer life expectancy and preserved late-life function. While ≥65 years remains a practical threshold in epidemiology, further stratification should be considered in future research to provide insights into the health and functional characteristics of elderly patients. Alongside these findings, interaction models identified sex-specific differences in comorbidity patterns. Males with SDB had lower odds of type 2 diabetes, stroke, and movement disorders compared to their male controls, whereas females showed a higher relative burden of these conditions. Conversely, males had stronger associations

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

with dyslipidemia and dementia. These findings suggest sex-specific variations in disease clustering that may reflect differences in symptom presentation, diagnostic timing, and underlying pathophysiology. Given that SDB remains underdiagnosed in women, such differences may contribute to variation in disease burden and long-term outcomes, including mortality(30,31).

The selection of chronic conditions for analysis was guided by a thorough review of the existing literature, identifying comorbidities either associated with or hypothesized to be linked to OSA(9,10,13,15,29,32,33). Some conditions were identified using prescription data, but this approach was limited to diagnoses with specific treatment regimens to reduce misclassification from overlapping medication use. The models did not account for the use of medications such as antihypertensives(26). Given the potential protective effects of such treatments, future studies should investigate the role of medication exposure and polypharmacy in shaping the relationship between SDB, multimorbidity, and clinical outcomes.

In the analysis of all-cause mortality, patients were matched prior to the outcome assessment, reducing the need for statistical adjustment. Nevertheless, we adjusted for comorbidities using the Quan-CCI index to evaluate whether mortality was primarily driven by morbidity.

The absence of a significant difference in adjusted mortality suggests that the elevated mortality in unadjusted analysis was largely explained by comorbid conditions rather than SDB itself. This may also indicate that the matching likely balanced key covariates, though residual confounding cannot be excluded. The Quan-CCI index was selected as the adjustment parameter due to its validation and widespread use in mortality analyses, making it a robust choice for this context (23). However, there remains a risk of overadjustment, as increased mortality risk has been observed in previous studies after adjusting for comorbidities(8,9,34).

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Strengths and limitations

The primary strength of this study lies in its large sample size of 21,555 individuals and a 17-year inclusion window, allowing for robust, longitudinal analysis. Additionally, the DNPR provides comprehensive coverage of the entire Danish population, increasing the generalizability of our findings. The registry also includes relevant sociodemographic variables and known confounders, which we used to effectively match controls. The registries also include healthcare cost data; although cost analyses were beyond the scope of the present study, health expenditures are likely associated with the observed pre-diagnostic burden, as recently demonstrated in younger and female populations(31).

However, several limitations must be acknowledged. First, there is a risk of misclassification among SDB patients. Despite the substantial sample size, SDB remains significantly underdiagnosed in Denmark. In this context, undiagnosed patients may have been misclassified as controls, which would likely result in a bias, underestimating the true association between SDB and comorbidities. Second, the case-control design introduces the potential for selection bias. Patients diagnosed with SDB may represent a higher-risk group, with increased exposure to risk factors such as smoking, alcohol use, substance abuse, low medication adherence, or higher BMI which are all data points not captured in the registries. The lack of individual-level BMI data is a key limitation, as obesity is a risk factor for both SDB and several chronic diseases(35). The recorded 12% obesity prevalence likely underestimates the true burden (36). However, recent meta-analysis data showed that only one-third of individuals with OSA were obese, suggesting SDB occurs independently of obesity, particularly in older adults(37,38). While residual confounding remains likely, our findings may reflect a broader relationship between SDB and multimorbidity

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

beyond obesity alone. Third, we were unable to assess SDB severity or treatment strategy, as metrics such as AHI and adherence are not captured in the DNPR. Because disease severity and treatment patterns likely shape multimorbidity profiles and outcomes, their absence limits interpretation. In this context, applying data-driven approaches such as latent class or cluster analyses may offer an alternative way to identify clinically relevant multimorbidity patterns within the SDB population.

Fourth, diagnostic variability was a concern, as registry data did not capture testing methods or hypopnea scoring. Updated criteria, variation in testing, and changing awareness over time may have introduced heterogeneity in case identification, particularly in older adults with atypical or underrecognized symptoms.

Finally, we acknowledge that the DNPR does not distinguish between subtypes of SDB, such as OSA, central sleep apnea, Cheyne-Stokes respiration, and mixed sleep apnea. As such, our study encompasses a heterogeneous SDB population. While OSA is expected to be the most prevalent subtype, the inclusion of patients with other forms of SDB, particularly those with coexisting conditions such as COPD, heart failure, or severe obesity, may introduce misclassification and bias. (1,2,37).

While this study highlights the relevance of screening for SDB in elderly, multimorbid patients, a need for high-quality randomized controlled trials (RCTs) to assess the impact of CPAP treatment in elderly patients remains. RCTs could overcome the inherent limitations of observational research. Future studies should also investigate CPAP compliance, assess changes in disease risk, and incorporate detailed clinical data to improve our understanding of SDB management in elderly adults.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Conclusion

This large-scale, registry-based case-control study demonstrates that SDB in patients aged 65 and above is associated with significantly increased odds of having multiple chronic conditions and elevated all-cause mortality compared to matched controls. The findings highlight the need for increased recognition and coordinated treatment of SDB in older adults with multiple chronic conditions.

Acknowledgements

None.

Ethical approval and consent to participate

This study was approved by the Danish Data Protection Agency (reference number: R-22069733). As the DNPR anonymized all patient data, individual and ethical approval was not required.

Consent for publication

Not applicable.

Funding

The project was supported by internal funding from the Danish Center for Sleep Medicine, Rigshospitalet, Denmark.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Credit author statement

Jeppe Suusgaard: Conceptualization, software, formal analysis, investigation, data curation, writing – original draft, writing – review & editing, visualization. **Christine Benn Christiansen:** Conceptualization, investigation, writing – review & editing, supervision. **Morten Kjøbek Lambert:** Conceptualization, investigation, writing – review & editing, supervision**. Mads Hashiba:** Conceptualization, investigation, writing – review & editing. **Michael Ibsen:** Conceptualization, methodology, software, formal analysis, resources, data curation. **Rikke Ibsen:** Conceptualization, methodology, software, formal analysis, resources, data curation. **Jakob Kjellberg:** Conceptualization, methodology, formal analysis, visualization.

Poul Jørgen Jennum: Conceptualization, methodology, validation, formal analysis, investigation, resources, data curation, writing – review & editing, visualization, supervision, project administration, funding acquisition.

Data Availability Statement

The full dataset on which this article is based cannot be shared publicly since that would compromise the privacy of the individuals who participated in the study. However, an anonymized version of the data used and analyzed is available from the corresponding authors upon reasonable request.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Tables

Table 1. Patient characteristics

Variable	Patients (N = 21 555)	Control (N = 86 212)
Sex, N (%)		
Female	6 273 (29%)	Matched
Male	15 282 (71%)	Matched
Age (years), Mean (SD)	71 (5)	Matched
Age group (years), N (%)		
65-69	9 871 (46%)	Matched
70-79	9 963 (46%)	Matched
≥ 80	1 721 (8%)	Matched
Region of Residence, N (%)		
Capital	5 877 (27%)	Matched
Zealand	2 942 (14%)	Matched
Southern Denmark	5 648 (26%)	Matched
Central Jutland	5 183 (24%)	Matched
Northern Jutland	1 905 (9%)	Matched
Cohabiting status, N (%)		
Married or cohabiting	15 202 (71%)	Matched
Single	6 353 (29%)	Matched
Employment status, N (%)		
Employed	2 542 (12%)	10 459 (12%)
Unemployed or leave due to illness	37 (<0.5%)	174 (<0.5%)
Disability pension	360 (1%)	1.133 (1%)
Education	45 (<0.5%)	189 (<0.5%)
Age pension	18 571 (86%)	74 257 (86%)
Education level, N (%)		
Primary	6 570 (31%)	28 407 (33%)
Secondary	481 (2%)	1 735 (2%)
Vocational	8 865 (41%)	34 462 (40%)
College Student – short	758 (4%)	2 933 (3%)
College student – medium	3 134 (15%)	11 496 (13%)
College student – long (+Ph.D.)	1 305 (6%)	5 398 (6%)
Unknown	442 (2%)	1 781 (2%)
Multimorbidity†, N (%)		
≥ 2 chronic diseases (all)	17 348 (81%)	50 883 (59%)
≥ 2 chronic somatic diseases†	16 673 (77%)	48 150 (56%)

Baseline variables: Patients are matched to controls in ratio 1:4 on sex, age, region of residence, and cohabiting status. † Chronic diseases excluding psychiatric diseases.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Table 2. Prevalence and odds ratio of comorbidities (aggregated into WHO disease classification) among patients with sleep-disordered breathing versus matched controls

WHO chapters	Patients (N = 21 555)		Control (N = 86 212)		OR	95% CI	p
	Cases (n)	Prevalence (%)	Cases (n)	Prevalence (%)			
2. Neoplasms (C00-D48)	5 240	24	18 271	21	1.20	[1.16;1.24]	<0.01
4. Endocrine, nutritional, and metabolic diseases (E00-E90)	7 879	37	16 351	19	2.52	[2.43;2.60]	<0.01
5. Mental and behavioral disorders (F00-F99)	2 014	9	5 972	7	1.40	[1.33;1.48]	<0.01
6. Diseases of the nervous system G00-G99)	4 038	19	8 548	10	2.11	[2.02;2.20]	<0.01
9. Diseases of the circulatory system (I00-I99)	12 364	57	30 678	36	2.52	[2.44;2.60]	<0.01
10. Diseases of the respiratory system (J00-J99)	5 596	26	11 341	13	2.35	[2.27;2.44]	<0.01
11. Diseases of the digestive system (K00-K93)	7 045	33	20 677	24	1.55	[1.50;1.60]	<0.01
14. Diseases of the genitourinary system (N00-N99)	5 662	26	14 668	17	1.75	[1.69;1.82]	<0.01

Number of cases (N) and prevalence (%) for relevant WHO chapters accumulated seven years prior to sleep-disordered breathing diagnosis in both cases and controls. Statistical significance (p) was calculated using conditional logistic regression, odds ratio (OR) and 95% confidence intervals (95% CI) were provided for each model.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Table 3. Prevalence and odds ratio of chronic diseases among patients with sleep-disordered breathing patients versus matched controls

Chronic diseases	Patients (N = 21 555)		Control (N = 86 212)		OR	95% CI	p
	Cases (n)	Prevalence (%)	Cases (n)	Prevalence (%)			
Cancer	5 240	24	18 271	21	1.20	[1.16;1.24]	<0.01
Endocrine or metabolic disease							
Diabetes type II	4 952	23	10 842	13	2.09	[2.01;2.17]	<0.01
Dyslipidemia	12 267	57	35 168	41	1.97	[1.91;2.04]	<0.01
Obesity	2 481	12	2 084	2	5.39	[5.07;5.74]	<0.01
Thyroid disease	1 824	9	4 731	6	1.62	[1.53;1.73]	<0.01
Mental and behavioral disorders							
Affective disorders	5 311	25	11 694	14	2.13	[2.05;2.21]	<0.01
Anxiety and stress-related disorders	2 473	12	7.326	9	1.41	[1.34;1.48]	<0.01
Other mental or behavioral ndisorders	318	2	870	1	1.48	[1.30;1.68]	<0.01
Neurological disorders							
Dementia and other neurodegenerative disorders	550	3	1 972	2	1.12	[1.02;1.24]	0.02
Movement disorders and neuroinflammatory disorders	491	2	1.140	1	1.74	[1.56;1.94]	<0.01
Stroke & TCI	2 645	12	6 196	7	1.85	[1.74;1.92]	<0.01
Other sleep disorders	543	3	179	<1	12.62	[10.63;14.99]	<0.01
Heart disease							
Atrial fibrillation/flutter	3 289	15	6 532	8	2.25	[2.15;2.35]	<0.01
Heart failure	1 832	9	3 065	4	2.57	[2.42;2.73]	<0.01
Hypertension	17 186	80	52 005	60	2.66	[2.57;2.76]	<0.01
Other CVD	7 718	36	19 364	23	1.96	[1.90;2.02]	<0.01
Respiratory disease							
Asthma	906	4	1 455	2	2.57	[2.36;2.80]	<0.01
COPD	2 224	10	3 994	5	2.39	[2.26;2.53]	<0.01
Gastrointestinal disease							
Reflux and gastritis	2 030	9	5 190	6	1.63	[1.54;1.72]	<0.01
Non-infectious colitis and enteritis	536	3	1 531	2	1.41	[1.28;1.56]	<0.01
Kidney & urinary tract disease							
Chronic kidney disease	681	3	1 266	2	2.21	[2.01;2.43]	<0.01
Other kidney and urinary disease	1 162	5	2 923	3	1.62	[1.52;1.74]	<0.01
Multimorbidity†, N (%)							
≥ 2 chronic diseases (all)	17 348	81	50 883	59	2.99	[2.88;3.10]	<0.01
≥ 2 chronic somatic diseases†	16 673	77	48 150	56	2.82	[2.72;2.92]	<0.01

Number of cases (N) and prevalence (%) for relevant chronic diseases accumulated seven years prior to the sleep-disordered breathing diagnosis in both cases and controls. Statistical significance (p) was calculated using conditional logistic regression, odds ratio (OR) and 95% confidence intervals (95% CI) were provided for each model. CVD = cardiovascular disease, COPD = Chronic obstructive pulmonary disease. † Chronic diseases excluding psychiatric diseases.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Table 4. Interaction analysis of sex differences in the association between case-control status and likelihood of chronic diseases

Diagnosis	Female			Male			Interaction estimate	p
	OR	95% CI	p	OR	95% CI	p		
Cancer	1.22	[1.15;1.31]	<0.01	1.19	[1.14;1.24]	<0.01	- 0,03	0.41
Endocrine or metabolic diseases								
Diabetes type II	2.34	[2.18;2.53]	<0.01	2.01	[1.92;2.10]	<0.01	- 0,16	<0.01
Dyslipidemia	1.84	[1.74;1.95]	<0.01	2.03	[1.96;2.11]	<0.01	0.09	<0.01
Obesity	5.20	[4.71;5.72]	<0.01	5.53	[5.11;6.00]	<0.01	0.05	0.41
Thyroid disease	1.57	[1.45;1.69]	<0.01	1.70	[1.56;1.86]	<0.01	0.08	0.16
Mental and behavioral disorders								
Affective disorders	2.21	[2.07;2.35]	<0.01	2.09	[2.00;2.19]	<0.01	- 0.05	0.41
Anxiety and stress-related disorders	1.42	[1.31;1.53]	<0.01	1.41	[1.32;1.50]	<0.01	0.01	0.99
Other mental or behavioral disorders	1.86	[1.52;2.28]	<0.01	1.26	[1:06;1.50]	<0.01	- 0.39	<0.01
Neurological disorders								
Dementia and other neurodegenerative disorders	0.83	[0.68;0.99]	<0.01	1.27	[1:13;1.42]	<0.01	0.41	<0.01
Movement disorders and neuroinflammatory disorders	2.13	[1.77;2.57]	<0.01	1.58	[1.39;1.80]	<0.01	- 0.30	<0.01
Stroke & TCI	2.06	[1.87;2.27]	<0.01	1.76	[1.66;1.86]	<0.01	- 0.15	<0.01
Other sleep disorders	14.73	[10.66;20.36]	<0.01	11.83	[9.66;14.39]	<0.01	- 0.19	0.31
Heart disease								
Atrial fibrillation/flutter	2.20	[1.99;2.43]	<0.01	2.26	[2.15;2.38]	<0.01	0.03	0.57
Heart failure	2.51	[2.19;2.88]	<0.01	2.59	[2.42;2.77]	<0.01	0.01	0.88
Hypertension	2.60	[2.43;2.78]	<0.01	2.69	[2.57;2.81]	<0.01	0.03	0.40
Other CVD	2.07	[1.94;2.20]	<0.01	1.92	[1.85;2.00]	<0.01	- 0.07	0.06
Respiratory disease								
Asthma	2.79	[2.45;3.19]	<0.01	2.43	[2.17;2.71]	<0.01	- 0.14	0.11
COPD	2.30	[2.15;2.46]	<0.01	2.61	[2.36;2.86]	<0.01	- 0.12	0.04
Gastrointestinal disease								
Reflux and gastritis	1.83	[1.67;2.01]	<0.01	1.54	[1.44;1.64]	<0.01	- 0.18	<0.01
Non-infectious colitis and enteritis	1.57	[1.33;1.84]	<0.01	1.33	[1.17;1.51]	<0.01	- 0.16	0.11
Kidney & urinary tract disease								
Chronic kidney disease	2.34	[1.90;2.87]	<0.01	2.18	[1.95;2.42]	<0.01	- 0.15	0.09
Other kidney and urinary disease	1.83	[1.57;2.13]	<0.01	1.58	[1.46;1.71]	<0.01	- 0.08	0.49

Conditional logistic regression models were applied separately for males and females, adjusted for age, cohabiting status, and region of residence. Odds ratios (OR) with 95% CI are reported for each comorbidity. The last two columns (to the right of the dotted line) show the interaction term between case–control status and sex (male = 1), with corresponding p-values. A positive interaction estimate indicates a stronger association in males, while a negative estimate indicates a stronger association in females.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Table 5. Cox hazard models of all-cause mortality in sleep-disordered breathing patients versus matched controls

	Cox hazard model			
	Reference	**HR**	**95% CI**	**p**
Cox-hazard model				
Unadjusted	Matched controls	1.09	[1.06;1.13]	<0.01
Cox-hazard model				
Adjusted	Matched controls	1.02	[0.99;1.05]	0.62
Quan CCI		1.40	[1.39;1.41]	<0.01
	Mortality characteristics			
	SDB patients	**Controls**		
Number of patients				
Deaths N (%)	5 357 (25%)	20 005 (23%)		
Censored N (%)	16 198 (75%)	66 207 (77%)		
Age at death mean (SD)	78.2 (6.4)	78.4 (6.6)		

P-values were calculated by comparing the incidence of all-cause mortality between patients with sleep-disordered breathing (SDB) and matched controls using a Cox proportional hazards model, adjusted for the Quan Charlson Comorbidity Index (Quan CCI). Hazard ratios (HRs) with 95% confidence intervals (CIs) are reported. Patient characteristics include the number (%) of deaths versus censored cases and the mean (SD) age at death.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

References

1. Senaratna C V, Perret JL, Lodge CJ, Lowe AJ, Campbell BE, Matheson MC, et al. Prevalence of obstructive sleep apnea in the general population: A systematic review. Sleep Med Rev. 2017 Aug;34:70–81.
2. Heinzer R, Vat S, Marques-Vidal P, Marti-Soler H, Andries D, Tobback N, et al. Prevalence of sleep-disordered breathing in the general population: the HypnoLaus study. Lancet Respir Med. 2015 Apr;3(4):310–8.
3. Gottlieb DJ, Punjabi NM. Diagnosis and Management of Obstructive Sleep Apnea: A Review. JAMA. 2020 Apr;323(14):1389–400.
4. Uyar M, Davutoglu V. An update on cardiovascular effects of obstructive sleep apnoea syndrome. Postgrad Med J. 2016 Sep;92(1091):540–4.
5. Dong JY, Zhang YH, Qin LQ. Obstructive sleep apnea and cardiovascular risk: meta-analysis of prospective cohort studies. Atherosclerosis. 2013 Aug;229(2):489–95.
6. Javaheri S, Peker Y, Yaggi HK, Bassetti CLA. Obstructive sleep apnea and stroke: The mechanisms, the randomized trials, and the road ahead. Sleep Med Rev. 2022 Feb;61:101568.
7. Boulos MI, Dharmakulaseelan L, Brown DL, Swartz RH. Trials in Sleep Apnea and Stroke: Learning From the Past to Direct Future Approaches. Stroke. 2021 Jan;52(1):366–72.
8. Jennum P, Tønnesen P, Ibsen R, Kjellberg J. All-cause mortality from obstructive sleep apnea in male and female patients with and without continuous positive airway pressure treatment: a registry study with 10 years of follow-up. Nat Sci Sleep. 2015;7:43–50.
9. Suusgaard J, West AS, Ponsaing LB, Iversen HK, Rauen K, Jennum PJ. Stroke recurrence and all-cause mortality in CPAP-treated sleep-disordered-breathing patients. J Stroke Cerebrovasc Dis. 2024 Dec;34(2):108204.
10. Bassetti CLA, Randerath W, Vignatelli L, Ferini-Strambi L, Brill AK, Bonsignore MR, et al. EAN/ERS/ESO/ESRS statement on the impact of sleep disorders on risk and outcome of stroke. European Respiratory Journal. 2020 Apr;55(4).
11. McEvoy RD, Antic NA, Heeley E, Luo Y, Ou Q, Zhang X, et al. CPAP for Prevention of Cardiovascular Events in Obstructive Sleep Apnea. N Engl J Med. 2016 Sep;375(10):919–31.
12. Suusgaard J, West AS, Frandsen R, Iversen HK, Kruuse C, Rauen K, et al. Sleepiness, fatigue, and obstructive sleep apnea in stroke patients. Journal of Stroke and Cerebrovascular Diseases [Internet]. 2025 May 19;
13. Palomäki M, Saaresranta T, Anttalainen U, Partinen M, Keto J, Linna M. Multimorbidity and overall comorbidity of sleep apnoea: a Finnish nationwide study. ERJ Open Res. 2022 Apr;8(2).
14. Bonsignore MR, Baiamonte P, Mazzuca E, Castrogiovanni A, Marrone O. Obstructive sleep apnea and comorbidities: a dangerous liaison. Multidiscip Respir Med. 2019;14:8.
15. Osorio RS, Martínez-García MÁ, Rapoport DM. Sleep apnoea in the elderly: a great challenge for the future. European Respiratory Journal [Internet]. 2022 Apr 28;59(4):2101649.
16. Nicholson K, Makovski TT, Griffith LE, Raina P, Stranges S, van den Akker M. Multimorbidity and comorbidity revisited: refining the concepts for international health research. J Clin Epidemiol. 2019 Jan;105:142–6.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

17. Keenan BT, Kim J, Singh B, Bittencourt L, Chen NH, Cistulli PA, et al. Recognizable clinical subtypes of obstructive sleep apnea across international sleep centers: a cluster analysis. Sleep. 2018 Mar;41(3).
18. Zinchuk A, Yaggi HK. Phenotypic Subtypes of OSA: A Challenge and Opportunity for Precision Medicine. Chest. 2020 Feb;157(2):403–20.
19. Ye L, Pien GW, Ratcliffe SJ, Björnsdottir E, Arnardottir ES, Pack AI, et al. The different clinical faces of obstructive sleep apnoea: a cluster analysis. Eur Respir J. 2014 Dec;44(6):1600–7.
20. Li S, Tan S, Liu D, Zhang K, Zhang Y, Wang B, et al. Comorbidities are associated with self-reported sleep-disordered breathing and insomnia: a cross-sectional study from China. Sleep Breath. 2023 Dec;27(6):2407–13.
21. Berry R. QS, Abreu A. The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications, Version 2.6. American Academy of Sleep Medicine. 2020;
22. Iber C, Ancoli-Israel S, Chesson AL, Quan SF. The AASM manual for the scoring of sleep and associated events: rules, terminology, and technical specification. American Academy of Sleep Medicine. 2007;
23. Quan H, Li B, Couris CM, Fushimi K, Graham P, Hider P, et al. Updating and validating the Charlson comorbidity index and score for risk adjustment in hospital discharge abstracts using data from 6 countries. Am J Epidemiol. 2011 Mar;173(6):676–82.
24. Mensah GA, Wei GS, Sorlie PD, Fine LJ, Rosenberg Y, Kaufmann PG, et al. Decline in Cardiovascular Mortality. Circ Res [Internet]. 2017 Jan 20;120(2):366–80. Available from: https://doi.org/10.1161/CIRCRESAHA.116.309115
25. Ali D, Qureshi S, Siddiqui H, Uddin MS, Waqas SA, Afridi MK, et al. Rising cardiovascular mortality among obstructive sleep apnea patients: United States epidemiological trends (1999-2019). Heart Lung. 2025;70:271–7.
26. Shiina K. Obstructive sleep apnea -related hypertension: a review of the literature and clinical management strategy. Hypertension Research [Internet]. 2024;47(11):3085–98. Available from: https://doi.org/10.1038/s41440-024-01852-y
27. Armentaro G, Condoleo V, Francica M, Severini G, Pastura CA, Divino M, et al. Association between nocturnal continuous positive airway pressure and renal function decline in a cohort of elderly patients with obstructive sleep apnoea syndrome—An observational study. Eur J Clin Invest [Internet]. 2025 Jul 28;n/a(n/a):e70098. Available from: https://doi.org/10.1111/eci.70098
28. Yeghiazarians Y, Jneid H, Tietjens JR, Redline S, Brown DL, El-Sherif N, et al. Obstructive Sleep Apnea and Cardiovascular Disease: A Scientific Statement From the American Heart Association. Circulation. 2021 Jul;144(3):e56–e67.
29. Jennum P, Ibsen R, Kjellberg J. Morbidity prior to a diagnosis of sleep-disordered breathing: a controlled national study. J Clin Sleep Med. 2013 Feb;9(2):103–8.
30. Morrish E, Shneerson JM, Smith IE. Why does gender influence survival in obstructive sleep apnoea? Respir Med. 2008 Sep;102(9):1231–6.
31. Jennum P, Ibsen R, Ibsen M, Andersen S, Kjellberg J. Long-term welfare consequences of sleep apnea in 20-64-year-olds - influence of gender: A nationwide cohort study. Sleep. 2025 Mar;
32. Smith R, Ronald J, Delaive K, Walld R, Manfreda J, Kryger MH. What are obstructive sleep apnea patients being treated for prior to this diagnosis? Chest. 2002 Jan;121(1):164–72.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

33. Hedner J, Grote L, Bonsignore M, McNicholas W, Lavie P, Parati G, et al. The European Sleep Apnoea Database (ESADA): report from 22 European sleep laboratories. Eur Respir J. 2011 Sep;38(3):635–42.
34. Jennum P, Tønnesen P, Ibsen R, Kjellberg J. Obstructive sleep apnea: effect of comorbidities and positive airway pressure on all-cause mortality. Sleep Med. 2017 Aug;36:62–6.
35. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. Lancet. 2017 Dec;390(10113):2627–42.
36. Gribsholt SB, Pedersen L, Richelsen B, Thomsen RW. Validity of ICD-10 diagnoses of overweight and obesity in Danish hospitals. Clin Epidemiol. 2019;11:845–54.
37. Esmaeili N, Gell L, Imler T, Hajipour M, Taranto-Montemurro L, Messineo L, et al. The relationship between obesity and obstructive sleep apnea in four community-based cohorts: an individual participant data meta-analysis of 12,860 adults. EClinicalMedicine [Internet]. 2025 May 1;83. Available from: https://doi.org/10.1016/j.eclinm.2025.103221
38. Messineo L, Bakker JP, Cronin J, Yee J, White DP. Obstructive sleep apnea and obesity: A review of epidemiology, pathophysiology and the effect of weight-loss treatments. Sleep Med Rev. 2024 Dec;78:101996.

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

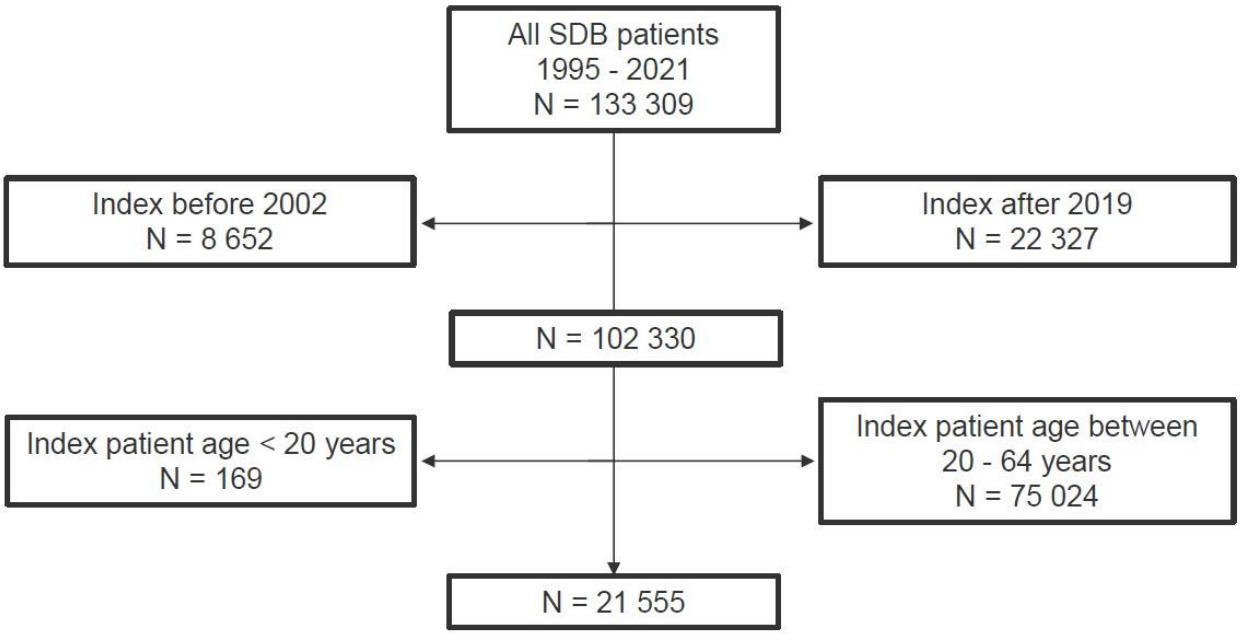


Figure 1

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

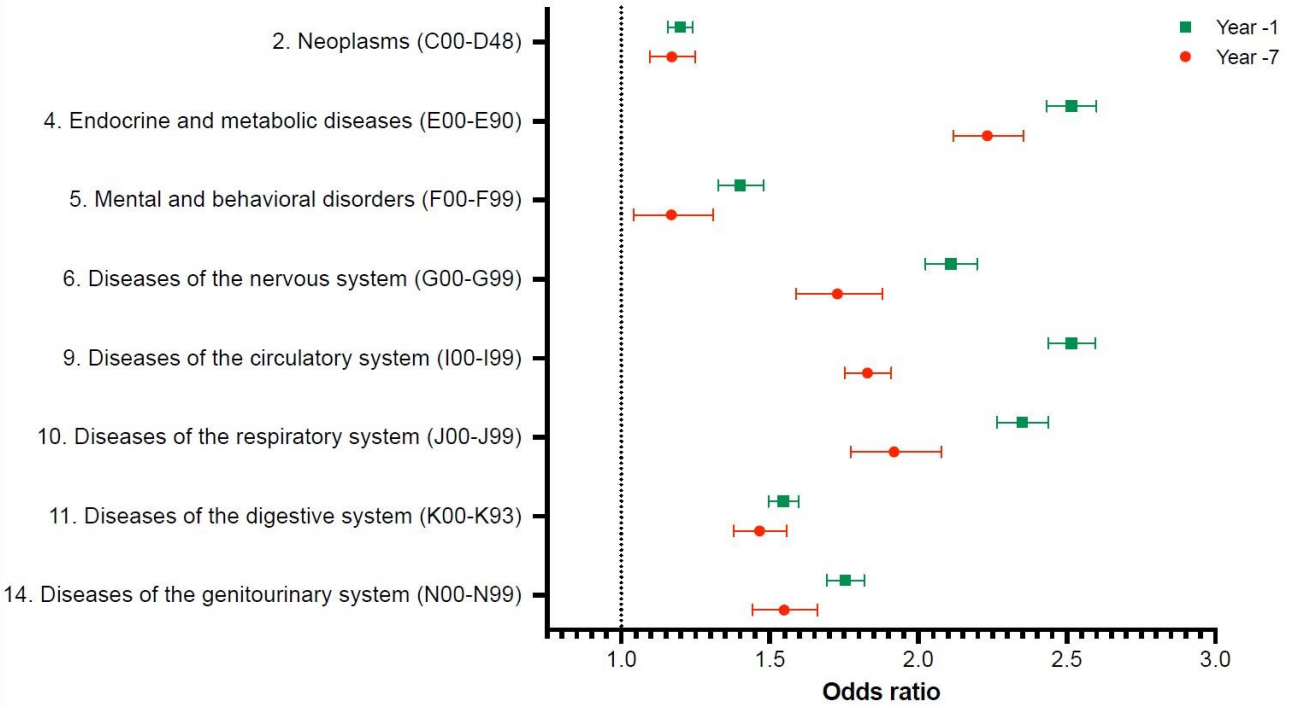


Figure 2

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

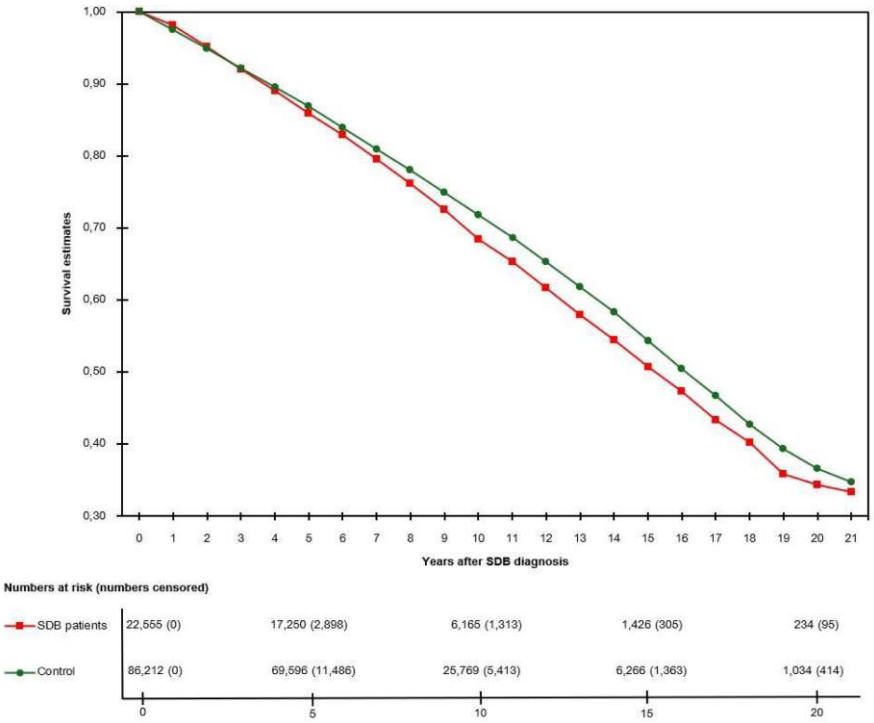


Figure 3

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Supplementary material

Table S1. Hypopnea criteria

Variable	American Academy of Sleep Medicine, recommended criteria	American Academy of Sleep Medicine, alternative criteria	Revised - American Academy of Sleep Medicine (after 2012)
Nasal flow	≥ 30%	≥ 50%	≥ 30%
Duration	≥ 90% of event	≥ 90% of event	NA
Desaturation (and/or arousal)	≥ 4%	≥ 3% (and/or arousal)	≥ 3% (and/or arousal)

The study utilized different diagnostic criteria to define sleep-disordered breathing over time. Initially, the recommended or alternative criteria of the American Academy of Sleep Medicine (AASM) were used.[19] Revised AASM criteria were implemented from 2012.[20] NA: not applicable (this criterion was abandoned when the 2012 update was implemented).

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

Table S2. WHO chapters and comorbidities with corresponding ICD/APC coding

WHO chapters and selected chronic diseases	ICD-10	APC	Rational
2. Neoplasms (C00-D48)	C00-D48		Association to OSA remains controversial, few studies do however point towards association.
4. Endocrine, nutritional, and metabolic diseases (E00-E90)			
Diabetes type 2	E11	A10*	Association to sleep-disordered breathing
Dyslipidemia	E78	C10A+C10B	Association to sleep-disordered breathing
Obesity	E66		Association to sleep-disordered breathing
Thyroid disease	E00-007	H03AA	Hypothyroidism associated with OSA
5. Mental and behavioral disorders (F00-F99)			
Mood [affective] disorders	F30-39	or at least 2 or more registrations of a purchased medication with the N06A ATC-code in one year	Mood and anxiety disorders associated with OSA
Anxiety, dissociative, stress-related, somatoform and other nonpsychotic mental disorders	F40-F48	or at least 2 or more registrations of a purchased medication with the N05B ATC-code in one year	Mood and anxiety disorders associated with OSA
Other mental or behavioral disorders	F20-29 + 50-99		Mood and anxiety disorders associated with OSA
6. Diseases of the nervous system (G00-G99)			
Dementia and other neurodegenerative disorders	F00-F09, G30-G32		Potential association to OSA
Movement disorders and neuroinflammatory disorders	G10-G13, G20-26, G35-37 excl. G47, G25.8		Neuroinflammatory diseases and Parkinson's disease have been associated with OSA
Stroke	I60-I69+G45		Stroke and TIA are associated with OSA
Other sleep disorders	G47 excl. G47.3		Hypersomnia is a main feature in OSA. Periodic limb movement disorder also associated with OSA
9. Diseases of the circulatory system (I00-I99)			
Atrial fibrillation and flutter	I48		Associated with OSA
Heart failure	I50		Associated with OSA
Hypertension	I10, I15	Patient are included with hypertension if collecting hypertension medication at least one time (Intention to treat is chosen as indicator for the patients having hypertension) •C02 – Antihypertensives •C03 – Diuretics •C07 - Beta blocking agents	Associated with OSA

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.

		•C08 - Calcium channel blockers •C09 - Agents acting on the renin-angiotensin system	
Other CVD	I10-I99 excl. I10, I15, I48, I50, I60-69		Associated with OSA
10. Diseases of the respiratory system (J00-J99)			
Asthma	J45-J46		Potential relationship between asthma and OSA
COPD	J44		Co-occurrence of COPD and OSA associated with high mortality risk
11. Diseases of the digestive system			
Reflux, gastritis, and ulcer	K20-K31		Gastro-esophageal reflux have been associated with OSA
Non-infectious colitis and enteritis	K50-52		Inflammatory bowel disease and OSA suggested to bidirectionally affect each other.
14. Diseases of the genitourinary system (N00-N99)			
Kidney & urinary tract disease	N00-N23, excl.N18		Uremia associated with OSA
Chronic kidney disease	N18		Uremia associated with OSA

The diseases or disease categories were selected based on professional opinion and related studies, that have shown an association or co-occurrence with obstructive sleep apnea (OSA)[9,10,12,14,23–26]. COPD = Chronic obstructive pulmonary disease, CVD = cardiovascular disease,

Downloaded from https://publications.ersnet.org on December 22, 2025 by guest. Please see licensing information on first page for reuse rights.