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SCIENTIFIC INVESTIGATIONS

The prevalence and comorbidities of obstructive sleep apnea in middle-aged men and women: the Busselton Healthy Ageing Study

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Study Objectives: Population surveys suggest the prevalence of obstructive sleep apnea (OSA) is high and increasing and that risk factors and outcomes differ between sexes. To explore these relationships we assessed current OSA prevalence, potential risk factors and comorbidities, and their changes relative to previous estimates in the same community.

Methods: All adults on the Busselton, Australia, electoral roll born 1946–1964 were invited to participate in a general health survey. Of the 5,037 (62% response rate) respondents, 3,686 successfully completed overnight 2-channel (oximetry, airflow) sleep studies. These were scored and categorized as nil, mild, moderate, or severe OSA based on apnea-hypopnea index (< 5, ≥ 5 to < 15, ≥ 15 to < 30, and ≥ 30 events/h, respectively). Sleep scores were related to participant characteristics and health profiles. OSA prevalence was compared with previous surveys in the community.

Results: Prevalences of any and moderate-severe OSA were 57.7% and 20.2% in males and 41.7% and 10.0% in females. Matched for age group, the prevalence of moderate-severe OSA was similar to that in 2007 (males 24.6%, females 9.8%) and was higher than in 1995 (males 4.7%). OSA was associated with age, body mass index, and alcohol intake in males and age and body mass index in females. Conditions associated with OSA included hypertension and current depression in males and hypertension, skin cancer, and diabetes in females.

Conclusions: Prevalence of OSA in a middle-aged, predominantly White population in 2010–2015 was high, has increased since 1995, and has remained stable since 2007. Sex differences exist in associated features, including potential risk factors and comorbidities.

Keywords: obstructive sleep apnea, prevalence, associations, comorbidities

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Estimates of prevalence of OSA in the general population range between 2% and 50% of men and 2% and 23% of women, depending on sampling and methods of measurement. The aim of this study was to estimate the prevalence and associations of OSA in a representative sample of middle-aged men and women from the Busselton, Australia, population and compare the results with those from previous studies in the same community.

Study Impact: Successive surveys of middle-aged populations demonstrate that the prevalence of OSA has increased in the last 25 years and is now very high, in both males and females. The potential risk factors and comorbidities associated with OSA differ between males and females.

INTRODUCTION

Obstructive sleep apnea (OSA) is a common chronic condition, with estimates of prevalence in the general population ranging between 2% and 50% of men and 2% and 23% of women depending on sampling and methods of measurement.[1–10] OSA is associated with significant morbidity, comorbidity,[2,11–16] and mortality.[17–19] Risk factors for OSA include male sex, increased body weight, cigarette smoking, increased alcohol intake, and increased neck circumference.[20] OSA is associated with increased risk of a number of adverse medical outcomes including hypertension,[11] cardiovascular disease,[14] atrial fibrillation,[21] and adverse social outcomes including disrupted sleep (patients and sleeping partners) and excessive daytime somnolence with increased risk of injury and motor vehicle accident, loss of productivity, and behavioral change.[22] Racial factors may also play a role in its prevalence,[6,8,21] and there is increasing evidence that risk factors for and outcomes of OSA may differ in males and females.[9]

Many of the prevalence studies were undertaken more than 15 years ago. A recent study has suggested a marked increase in the prevalence of OSA in the general population.[9] This was partly attributed to more sensitive measurements. Relatively few studies have examined changes in OSA prevalence over time within the same community. Such studies suggest that the prevalence of OSA is increasing, perhaps due to the "obesity epidemic."[23]

Busselton is a small coastal city of about 36,000 residents in the southwest of Western Australia. The prevalence of OSA in

Busselton has been estimated on 2 previous occasions. In the early 1990s, using a MESAM IV (Madaus Medizin-Elektronik, Freiburg, Germany) device on a random sample of 294 middle-aged men, Bearpark and colleagues[2] found that 10% of men had a respiratory disturbance index greater or equal to 10 events/h. In 2005–2007, using an ApneaLink device (ResMed, San Diego, CA) on a random sample of 793 middle-aged participants, Simpson and colleagues[24] found a prevalence of moderate-severe OSA of 12.4% in men and 5.7% in women.

These data provide a basis for estimating changes in OSA prevalence and associated features, including risk factors and comorbidities, in successive middle-aged populations drawn from the same community. The aim of this study was to make this comparison, by studying a representative sample of middle-aged men and women from the Busselton population and comparing the results with those from previous studies of this community.

METHODS

Study population and participants

A community-based cross-sectional survey of adults born between 1946 and 1964 and resident in Busselton was undertaken from May 2010 to December 2015. The details of the study protocol and methods are described.[25] All eligible (8,206 alive and mobile) of 9,176 adults registered on the compulsory national electoral roll were invited to attend the survey. Contact was made with 6,783 of those eligible, and 76% of those contacted participated, so that the participation rate among all eligible adults was 62%. The study received ethics approval from The University of Western Australia Human Research Ethics Committee (No. RA/4/1/2203) and written, informed consent was obtained from each participant. There were 5,107 participants and data were available for analysis in 5,037.

Data collection

All participants completed a comprehensive questionnaire that included socioeconomic information, self-reported past medical history, self-reported OSA and its treatment, sleepiness while driving, OSA risk assessed by the Berlin sleep questionnaire,[26] daytime sleepiness assessed by the Epworth Sleepiness Scale (ESS),[27] current depression (defined as use of antidepressant medication and/or as indicated by "Consider Major Depressive Disorder" criteria on the Patient Health Questionnaire-9, PHQ9)[28] medications, cigarette and alcohol intake, diet, and physical activity. Of these, 5,100 attended a 4-hour health assessment visit at the study center in Busselton that included measurement of height, weight, blood pressure, and spirometry, and a blood sample was taken for estimation of serum blood sugar and cholesterol. At the visit, participants were given the opportunity of overnight monitoring of breathing during sleep. Those who agreed (n = 3,745) were provided with a monitoring device and instructed in its correct use that evening or a following evening, and they returned it to the testing center the next day. Acceptable data were available for analysis from 2,686 participants (including 86 with a previous diagnosis of OSA). Of the 1,355 participants who did not have a sleep study, 189 had a previous diagnosis of OSA. Other reasons for nonparticipation were not recorded.

Analysis of sleep studies

Overnight sleep studies were conducted using a dual-channel (nasal flow and oximetry) ApneaLink device (firmware version 04.08, software version 8.00). This device measures nasal flow (using a nasal cannula/pressure transducer system, recording the inverse square root of pressure as an index of flow [sample rate 100 Hz]) and pulse oximetry (Nonin XPod 3012 with a Nonin 7000A finger probe [sample rate 1 Hz]; Nonin, Hudiksvall, Sweden). The sleep study was judged acceptable if it was ≥ 4 h duration, and both flow and oxygen saturation data were present for ≥ 90% of the recording time. Sleep data were analyzed using the automated ApneaLink software. Respiratory events were scored according to default criteria for this device (version 8). An apnea was defined as a decrease in airflow by 80% of baseline (duration 10–80 seconds). A hypopnea was defined as a decrease in airflow ≥ 30% of baseline plus 4% desaturation or a reduction of airflow ≥ 50% of duration 10–100 seconds. The definition for apnea-hypopnea index (AHI) was the number of apneas plus hypopneas per hour of estimated sleep with acceptable signal quality.

OSA severity was defined as mild, moderate, or severe using AHI cutoffs of 5, 15, and 30 events/h, respectively. OSA syndrome was defined based on AHI plus excessive daytime sleepiness, defined as an Epworth Sleepiness Scale score of > 10.9 Five different categories were defined for the purpose of analysis as follows: (1) any OSA (AHI > 5 events/h), (2) moderate-severe OSA (AHI ≥ 15 events/h), (3) severe OSA (AHI ≥ 30 events/h, (4) any OSA syndrome (AHI ≥ 5 events/h and ESS > 10), and (5) moderate-severe OSA syndrome (AHI ≥ 15 events/h and ESS > 10).

Statistical methods

Statistical analyses were performed using SAS 9.4 or the R environment for statistical computing.[29] Summary statistics included counts and percentages for categorical variables and means and standard deviations for continuous variables. As only 2,686 participants provided ApneaLink data from which an AHI could be obtained, this information was missing for 47% of individuals. To estimate the prevalence of AHI in the Busselton Healthy Ageing Study (BHAS) and to account for this missing information, we used multiple imputation, specifically the MICE method (multiple imputation by chained equations) based on all other variables in the data. We simulated 40 datasets of imputed data, and an overall estimate of prevalence was calculated based on these imputed datasets and separately for 4 different categories of OSA or OSA syndrome. All further analyses were performed on a complete-case basis.

The prevalence of moderate-severe sleep apnea was compared between the present study and surveys published in 1995[2] and 2013.[24] The age range of participants was similar in the present study and the 1995 survey; however, all adults were included in the 2013 survey. Therefore, the prevalence of moderate-severe sleep apnea in the 2013 survey was recalculated, confined to males and females in the same age range as the present study.

Univariate and multivariate logistic regressions were conducted to investigate the correlates of OSA and OSA syndrome. Potential correlates included age, body mass index,

number of glasses of alcohol per week, ESS (when the outcome was based on AHI alone), education, occupation, marital status, smoking status, high-risk classification based on the Berlin questionnaire, sleepy driving, and whether the participant underwent spirometry. The estimated odds ratios (ORs), 95% confidence intervals (CIs), and *P* values are provided for all explanatory variables.

Univariate and multivariate logistic regressions were also used to assess the relationships between OSA and OSA syndrome and the medical history outcomes. The estimated odds ratio with 95% confidence interval was reported for each OSA criterion in relation to each of the medical history outcomes after 4 levels of adjustment for potential confounders. Model A: adjusted for demographics (age, education, occupation, and marital status); model B: model A further adjusted for lifestyle factors (body mass index [BMI], number of glasses of alcohol per week, and smoking status); model C: model B further adjusted for sleep variables (ESS, Berlin high risk, and sleepy driving); model D: model C further adjusted for the lung function assessed by the forced expiratory volume in 1 second (FEV_1), as a percentage of the predicted value.[30] Since the additional variables in models C and D did not change the overall relationships between OSA and medical history outcomes, results for model B are shown. All analyses were conducted separately for males and females.

RESULTS

The baseline characteristics of the cohort are shown in **Table 1**. Of the 5,037 participants, 45.1% were males and 54.9% were females, aged 58.1 ± 5.9 years (mean ± standard deviation) and 57.9 ± 5.7 years, respectively. In males, sleep study data were available in 52.4% and mean AHI was 9.1 ± 10.3 events/h. In females, sleep study data were available in 54.0% and mean AHI was 6.0 ± 7.8 events/h ($P < .0001$ compared with males). In addition, more males had severe OSA. Males exhibited slightly higher BMI and FEV_1, higher reported alcohol consumption, and were more often currently smoking, were in paid employment, reported OSA, and experiencing (or were taking medications for) diabetes or hypertension. There were no significant differences between males and females in age or level of education attained.

Comparison of participants from the BHAS who did or did not have a sleep study (**Table S1** in the supplemental material) showed that males who did not have a sleep study weighed more, drank more alcohol, more often smoked, or more often reported OSA. Females who did not have a sleep study weighed less, reported less daytime sleepiness, and more often reported OSA.

Prevalence of OSA

Among those who completed the sleep study (n = 2,686), the prevalence of OSA for males and females were: any OSA, 57.5% and 40.7%; moderate-severe OSA, 20.2% and 10.0%; and severe OSA, 5.1% and 2.0%, respectively. The prevalence of OSA syndrome for males and females was: any OSA syndrome, 8.3% and 4.8%; and moderate-severe OSA syndrome, 3.6% and 1.3%, respectively (**Table 2**). Using multiple imputation to estimate AHI values for those individuals who did not have any sleep study data, the prevalence of OSA was re-estimated for all individuals (n = 5,037, **Table S2**). The imputed data estimated slightly higher mean AHI values in males (prevalence of moderate-severe OSA increased from 20.2% to 21.9%) and slightly lower values in females (prevalence of moderate-severe OSA decreased from 10.0% to 9.7%).

Changes in prevalence of OSA in the Busselton population

Compared with participants from the same age group in the 2 other studies in the Busselton population, the prevalence of "any" sleep apnea (respiratory disturbance index > 5 events/h in 1995 or AHI > 5 events/h in 2010) for males increased from 26% in 1995 to 58% in the 2010–2015 sample. The prevalence of moderate-severe OSA increased in males from 4.7% in 1995[2] to 24.6% in 2007[24] and was 20.2% in the present study (**Table 3**). In females, there were no data from 1995; however, the prevalence of moderate-severe OSA was 9.8% in 2007 and 10.0% in the present study.

Associations with OSA

The associations with moderate-severe OSA are shown in **Table 4**. In males, moderate-severe OSA was significantly associated with increased age, BMI, number of glasses of alcohol per week, ESS, and high risk of OSA based on the Berlin questionnaire. In females, moderate-severe OSA was significantly associated with increased age, BMI, a high risk based on the Berlin questionnaire, and reduced tertiary education but not with number of glasses of alcohol per week or ESS. The factors associated with severe OSA were similar (**Table S3**), although in males severe OSA did not correlate with age or ESS and in females severe OSA was only correlated with high risk of OSA based on the Berlin questionnaire.

The associations with any OSA syndrome are shown in **Table 5**. In males, any OSA syndrome correlated positively with high risk of OSA based on the Berlin questionnaire and sleepy driving, and negatively with tertiary education and reporting having quit smoking or never smoking. In females, any OSA syndrome correlated positively with increased age and BMI, a high risk of OSA based on the Berlin questionnaire, and those who experience sleepy driving. Females who were retired compared with those in paid employment had decreased odds of any OSA syndrome. Moderate-severe OSA syndrome correlated with increased BMI and high risk of OSA based on the Berlin questionnaire in both males and females (**Table S4**).

The relationships between associated features and severity of OSA are summarized in **Table 6**. For both males and females the severity of OSA increased with increasing BMI. The severity of OSA was directly related to alcohol consumption (glasses per week) in males but inversely related to alcohol consumption in females. Daytime sleepiness increased with increasing severity of OSA in males but not in females.

Associations of OSA with medical history outcomes

Adjusting only for participant demographics, males with moderate-severe OSA had an increased odds of hypertension (OR = 1.81; 95% CI, 1.35–2.45; $P < .001$) and current depression

Table 1—Participant characteristics of the Busselton Healthy Ageing Study baseline (n = 5,037).

Characteristic	Male (n = 2,271, 45.1%)	Female (n = 2,766, 54.9%)	*P*
Age, y	58.1 ± 5.9	57.9 ± 5.7	.2306
Body mass index, kg/m^2	28.5 ± 4.1	27.9 ± 5.5	< .0001
Number of glasses of alcohol per week	17.0 ± 15.9	7.0 ± 8.46	< .0001
Epworth Sleepiness Scale	6.0 ± 3.8	5.3 ± 3.7	< .0001
Education			
Secondary school or less	1,175 (51.7)	1,361 (49.2)	.1979
Other educational institution (eg, TAFE, college)	671 (29.5)	855 (30.9)	
University	425 (18.7)	550 (19.9)	
Occupation			
In paid employment or self-employed	1,647 (72.5)	1,608 (58.1)	< .0001
Retired	450 (19.8)	709 (25.6)	
Other	174 (7.7)	449 (16.2)	
Marital status			
Single/widowed/divorced/separated	292 (12.9)	570 (20.6)	< .0001
Married/de facto	1,979 (87.1)	2,196 (79.4)	
Smoking status			
Never	966 (42.5)	1,405 (50.8)	< .0001
Former	1,042 (45.9)	1,122 (40.6)	
Current	263 (11.6)	239 (8.6)	
Self-reported OSA	194 (8.5)	79 (2.9)	< .0001
Completed spirometry	1,829 (80.5)	2,406 (87)	< .0001
FEV_1 percent predicted	95.2 ± 15.1	94.1 ± 14.9	.0202
Completed ApneaLink study	1,191 (52.4)	1,495 (54.0)	.2558
AHI, events/h*	9.1 ± 10.3	6.0 ± 7.8	< .0001
Epworth Sleepiness Scale > 10	154 (12.9)	160 (10.7)	.0004
Berlin questionnaire "high risk"	831 (36.6)	705 (25.5)	< .0001
Sleepy driving	372 (16.4)	240 (8.7)	< .0001
Cancer (any)	322 (14.2)	410 (14.8)	.5187
Cancer (skin)	208 (9.2)	206 (7.4)	.0278
Cancer (nonskin)	121 (5.3)	222 (8.0)	.0002
Heart disease	139 (6.1)	53 (1.9)	< .0001
Stroke	62 (2.7)	44 (1.6)	.0051
Diabetes	163 (7.2)	133 (4.8)	.0004
Hypertension	1,035 (45.6)	1,056 (38.2)	< .0001
COPD (reported)	142 (6.3)	147 (5.3)	.1542
Current depression	353 (15.5)	619 (22.4)	< .0001
Asthma	298 (13.1)	516 (18.7)	< .0001

Table shows mean ± SD or count (percent). *Only 2,686 individuals (1,191 males and 1,495 females) had a sleep study with acceptable data. AHI = apnea-hypopnea index, COPD = chronic obstructive pulmonary disease—reported, ESS = Epworth Sleepiness Scale, FEV_1 = forced expiratory volume in 1 second, OSA = obstructive sleep apnea, SD = standard deviation, TAFE = technical and further education.

(OR = 1.75; 95% CI, 1.20–2.55; *P* = .004) (**Table 7**). When corrected for participant demographics and lifestyle factors, males with moderate-severe OSA had an increased odds of current depression (OR = 1.70; 95% CI, 1.15–2.40; *P* ≤ .007). Adjusting only for participant demographics, females with moderate-severe OSA had an increased odds of skin cancer (OR = 1.80; 95% CI, 1.07–3.04; *P* = .027), hypertension (OR = 1.49; 95% CI, 1.04–2.12; *P* = .030), and diabetes (OR = 1.98; 95% CI, 1.05–3.73; *P* = .035). When corrected for participant demographics and lifestyle factors, females with moderate-severe

Table 2—Prevalence of OSA and OSA syndrome*.

	Male (n = 1,191)	Female (n = 1,495)
AHI ≥ 5 events/h	687 (57.7%)	608 (40.7%)
AHI ≥ 15 events/h	241 (20.2%)	149 (10.0%)
AHI ≥ 30 events/h	61 (5.1%)	30 (2.0%)
AHI ≥ 5 events/h and ESS > 10	99 (8.3%)	72 (4.8%)
AHI ≥ 15 events/h and ESS > 10	43 (3.6%)	20 (1.3%)

*OSA syndrome was defined based on AHI and ESS. AHI = apnea-hypopnea index, ESS = Epworth Sleepiness Scale, OSA = obstructive sleep apnea, SD = standard deviation.

Table 3—Prevalence of moderate-severe OSA (AHI > 15 events/h) in 3 studies of the Busselton population.

Reference	Device	n	Age Range (y)	Monitoring	Prevalence OSA	
					Male	Female
2	MESAM IV	400	40–69 (males only)	Snoring, oximetry, body position, heart rate	4.7%	—
24	ApneaLink	793	18–80	Oximetry	12.4%	5.7%
24	ApneaLink	359	46–69*	ApneaLink	24.6%	9.8%
Present study	ApneaLink	2,707	46–69	Oximetry, nasal flow	20.2%	10.0%

*Recalculated from original data. AHI = apnea-hypopnea index, OSA = obstructive sleep apnea.

OSA had a decreased odds of current depression (OR = 0.59; 95% CI, 0.38–0.93; $P = .024$) and increased odds of skin cancer (OR = 1.80; 95% CI, 1.05–3.08; $P = .033$).

DISCUSSION

This study of males and females born between 1946 and 1964 from a predominantly White population has shown that OSA is a substantial public health problem, the prevalence of which appears to be increasing relative to previous estimates drawn from the same community. The prevalence of any OSA (AHI ≥ 5 events/h) in the present study was very high in both males and females, and in males moderate-severe OSA had increased 4- to 5-fold over a 20-year period. Moderate-severe OSA has also increased in females compared with previous studies in other populations. This study found no significant increase in the prevalence of OSA since 2007. Features associated with OSA remain age and body weight in both men and women and alcohol consumption in men. OSA was associated with depression (increased odds) in males and skin cancer and depression (decreased odds) in females. Symptomatic OSA was common and associated with increased sleepiness when driving.

This study was undertaken over a 5-year period, commencing in 2010, in males and females born between 1946 and 1964, so that participants were between 46 and 69 years of age at the time of study. The aim of the Busselton Healthy Ageing Study was to estimate the prevalence of multimorbidity and its effects on physical and cognitive function in a middle-aged general population. The response rate from all potentially eligible participants (all those on the electoral roll—voting is compulsory in Australia) was high at 62%. The study population is predominantly White with no Aboriginal participants and few Asian participants (< 1%). The estimation of the prevalence of OSA and OSA syndrome was similar in participants of the BHAS who did or did not (imputed prevalence) undertake the home sleep study.

The estimation of the prevalence of OSA and OSA syndrome in the present study was made using data from a level 4 monitoring system, a 1- or 2-channel device (ApneaLink, ResMed). Therefore differences in accuracy, scoring mechanisms and algorithms, and in scoring criteria, compared with previous studies in this population and compared with in-laboratory polysomnography, are to be expected. The ApneaLink device has been shown to correlate well with in-laboratory polysomnography (level 1) for patients with moderate (AHI > 15–30 events/h) to severe (AHI > 30 events/h) OSA[31] and has good specificity but reduced sensitivity for mild OSA (AHI > 5–15 events/h), especially in nonobese individuals. The accuracy of manual scoring was not significantly different from automated scoring.[32] Therefore, use of this device would tend to underestimate, rather than overestimate the prevalence of OSA, particularly mild OSA, in the community. It is possible that the increased prevalence of OSA observed in men in the Busselton population between 1995 and 2013 was due to reduced sensitivity of the MESAM device in

Table 4—Associations between the participant characteristics and moderate-severe sleep apnea (AHI ≥ 15 events/h).

	Male				Female			
Characteristic	**AHI < 15 events/h**	**AHI ≥ 15 events/h**	**OR (95% CI)**	***P***	**AHI < 15 events/h**	**AHI ≥ 15 events/h**	**OR (95% CI)**	***P***
n, %	950 (79.8)	241 (20.2)			1,346 (90.0)	149 (10.0)		
Age, y	57.6 ± 5.9	59.8 ± 5.7	1.061 (1.029–1.094)	.0002	57.4 ± 5.8	60.5 ± 5.3	1.095 (1.05–1.143)	< .0001
Body mass index (kg/m^2)	27.9 ± 3.7	29.9 ± 4.6	1.09 (1.047–1.134)	<.0001	27.7 ± 5.2	31.3 ± 6.9	1.074 (1.039–1.109)	< .0001
Alcohol, glasses per week	15.1 ± 14.4	18.6 ± 17.0	1.014 (1.005–1.024)	.004	6.9 ± 8.2	5.1 ± 8.4	0.98 (0.956–1.006)	.1281
Epworth Sleepiness Scale	6.0 ± 3.7	6.7 ± 4.1	1.05 (1.008–1.094)	.0191	5.6 ± 3.7	6.1 ± 3.6	1.016 (0.968–1.066)	.5164
Education								
Secondary school or less	465 (78.4)	128 (21.6)	1		623 (88.1)	84 (11.9)	1	
Other educational institution (eg, TAFE, college)	281 (79.8)	71 (20.2)	0.95 (0.673– 1.341)	.7682	444 (93.1)	33 (6.9)	0.611 (0.391–0.955)	.0113
University	204 (82.9)	42 (17.1)	1.001 (0.663–1.511)	.8959	279 (89.7)	32 (10.3)	1.157 (0.727–1.841)	.0887
Occupation								
In paid employment or self-employed	710 (81.7)	159 (18.3)	1		795 (93.1)	59 (6.9)	1	
Other	63 (77.8)	18 (22. 2)	0.983 (0.539–1.793)	.8193	208 (86.3)	33 (13.7)	1.574 (0.965–2.57)	.1362
Retired	177 (73.4)	64 (26. 6)	1.11 (0.729–1.688)	.6324	343 (85.75)	57 (14.25)	1.248 (0.752–2.071)	.9815
Smoking								
Current	79 (79.0)	21 (21.0)	1		105 (92.1)	9 (7.9)	1	
Ex	421 (76.3)	131 (23.7)	0.934 (0.533–1.637)	.6947	551 (89.9)	62 (10.1)	1.097 (0.51–2.363)	.7322
Never	450 (83.5)	89 (16.5)	0.756 (0.424–1.348)	.2013	690 (89.8)	78 (10.2)	1.023 (0.473–2.209)	.9201
Berlin questionnaire high risk								
No	645 (85.8)	107 (14.2)	1		993 (93.5)	69 (6.5)	1	
Yes	305 (69.5)	134 (30.5)	1.769 (1.268–2.469)	.0008	353 (81.5)	80 (18.5)	2.302 (1.548–3.425)	< .0001
Sleepy driving								
No	776 (79.0)	206 (21.0)	1		1,218 (90.2)	133 (9.8)	1	
Yes	174 (83.3)	35 (16.7)	0.667 (0.432–1.03)	.0677	128 (88. 9)	16 (11.1)	1.26 (0.684–2.323)	.4587

AHI = apnea-hypopnea index, CI = confidence interval, OR = odds ratio, TAFE = technical and further education.

Table 5—Associations between participant characteristics and mild sleep apnea syndrome (AHI ≥ 5 events/h and ESS >10).

	Male				Female			
Characteristic	**No**	**Yes**	**OR (95% CI)**	***P***	**No**	**Yes**	**OR (95% CI)**	***P***
n, %	1,092 (91.7)	99 (8.3)			1,423 (95.2)	72 (4.8)		
Age, y	58.0 ± 5.9	58.5 ± 6	1.035 (0.991–1.08)	.1255	57.7 ± 5.8	59.2 ± 5.2	1.096 (1.035–1.16)	.0017
Body mass index, kg/m^2	28.1 ± 3.9	29.9 ± 5.1	1.053 (0.997–1.111)	.0617	27.9 ± 5.4	32.3 ± 6.4	1.09 (1.044–1.138)	<.0001
Alcohol, glasses per week	15.9 ± 15.0	14.5 ± 14.6	0.989 (0.974–1.004)	.1412	6.7 ± 8.3	5.8 ± 6.9	0.994 (0.963–1.027)	.7315
Education								
Secondary school or less	534 (90.1)	59 (9.9)	1		666 (94.2)	41 (5.8)	1	
Other educational institution (eg, TAFE, college)	322 (91.5)	30 (8.5)	0.802 (0.496–1.298)	.389	458 (96.0)	19 (4.0)	0.634 (0.35–1.147)	.3166
University	236 (95.9)	10 (4.1)	0.405 (0.199–0.825)	.0254	299 (96.1)	12 (3.9)	0.739 (0.368–1.484)	.8282
Occupation								
In paid employment or self-employed	793 (91.3)	76 (8.7)	1		812 (95.1)	42 (4.9)	1	
Other	74 (91.4)	7 (8.6)	0.654 (0.271– 1.578)	.6657	227 (94.2)	14 (5.8)	0.853 (0.433–1.68)	.3753
Retired	225 (93.4)	16 (6.6)	0.631 (0.323–1.232)	.5038	384 (96.0)	16 (4.0)	0.399 (0.188–0.845)	.0224
Smoking								
Current	86 (86.0)	14 (14)	1		110 (96.5)	4 (3.5)	1	
Ex	507 (91.8)	45 (8.2)	0.374 (0.186–0.751)	.0451	577 (94.1)	36 (5.9)	1.378 (0.459– 4.138)	.2728
Never	499 (92.6)	40 (7.4)	0.374 (0.185–0.757)	.0491	736 (95.8)	32 (4.2)	0.915 (0.296– 2.828)	.4775
Berlin questionnaire high risk								
No	716 (95.2)	36 (4.8)	1		1,036 (97.6)	26 (2.4)	1	
Yes	376 (85.6)	63 (14.4)	2.66 (1.637, 4.322)	<.0001	387 (89.4)	46 (10.6)	2.889 (1.656– 5.04)	.0002
Sleepy driving								
No	917 (93.4)	65 (6.6)	1		1,295 (95.9)	56 (4.1)	1	
Yes	175 (83.7)	34 (16.27)	2.93 (1.83, 4.692)	<.0001	128 (88.9)	16 (11.1)	3.458 (1.824– 6.554)	.0001

AHI = apnea-hypopnea index, CI = confidence interval, ESS = Epworth Sleepiness Scale, OR = odds ratio, TAFE = technical and further education.

Table 6—Relationships between OSA severity and sex, BMI, alcohol intake, and Epworth Sleepiness Scale.

	Male				Female			
	AHI < 15 events/h	AHI = 15–29.9 events/h	AHI ≥ 30 events/h	*P*	AHI < 15 events/h	AHI = 15–29.9 events/h	AHI ≥ 30 events/h	*P*
n (%)	950 (79.8)	180 (15.1)	61 (5.1)		1,346 (90.0)	119 (8.0)	30 (2.0)	
BMI, kg/m^2	27.9 ± 3.7	29.50 ± 4.3	31.27 ± 5.3	<.0001	27.71 ± 5.2	31.07 ± 6.4	32.31 ± 8.5	<.0001
Alcohol, glasses per week	15.1 ± 14.4	17.41 ± 15.9	22.01 ± 19.6	.0006	6.86 ± 8.2	5.16 ± 8.8	5.03 ± 6.7	.0503
Epworth Sleepiness Scale	5.97 ± 3.7	6.62 ± 4.1	7.13 ± 4.0	.0113	5.58 ± 3.7	6.19 ± 3.7	5.93 ± 3.5	.2016

AHI = apnea-hypopnea index, BMI = body mass index, OSA = obstructive sleep apnea.

1995. However this seems unlikely since the MESAM device recorded snoring, oximetry, body position, and heart rate. In contrast, the present study (2010–2015) and that of Simpson et al[24] (2007) measured only oximetry or oximetry and nasal flow, and recorded similar prevalence values for OSA in men and women. In addition, the MESAM device was scored manually and validated against standard, in-laboratory polysomnography in 10 participants.2

In agreement with the HypnoLaus study,[9] we found that the prevalence of OSA has increased markedly over the last 15–20 years. In the HypnoLaus study,[9] which used in-laboratory polysomnography, the increase in prevalence of OSA was attributed to the "obesity epidemic" or to increased sensitivity of measurement or both. In our study we used a less-sensitive instrument and found that the presence and severity of OSA were associated with BMI in both males and females. The average BMI for the BHAS participants was higher than that seen on the HypnoLaus study (25.6 kg/m^2). The high prevalence of overweight and obesity in the BHAS participants (~65%) is similar to that seen across Australia.[39] The prevalence of obesity and overweight has increased greatly between 1995 and 2007 but has remained much the same between 2007 and 2015, matching the trends observed in the prevalence of OSA.

The increase in prevalence of any or moderate-severe OSA over the last 15–20 years observed in the present study and in the HypnoLaus study[9] reflects observations of studies published pre-2010 reporting prevalence of any OSA (AHI ≥ 5 events/h) of 17% to 31% in males and 6% to 28% in females[3,32–34] and studies published post-2010 reporting prevalence of any OSA of 34% to 84% in males and 17% to 61% in females.[9,23,35] For moderate-severe OSA (AHI ≥ 15 events/h), we observed a similar high prevalence in the present study and in 2007 in the same population.[24] This was an increase (for men) compared with 1995,[2] although not a higher prevalence than observed in the HypnoLaus study (50% in men and 23% in women).[9]

The present study was confined to participants aged 46–69 years. Many of the previous studies have included individuals aged anywhere from 20–80 years of age, including the previous study in the Busselton population. In 2007, the Busselton population showed a prevalence of moderate-severe OSA of 12.4% for males and 5.7% for females, including all participants. However, if only those aged between 46 and 69 years were observed, the prevalence of moderate-severe OSA was similar to values obtained in the present study, although not as high as in the HypnoLaus study.[9]

Since only 53% of the BHAS participants underwent a sleep study and had data available for analysis, selection bias may have altered our results. This sampling bias would result in an underestimation of the true prevalence of OSA in this population. If we add participants with reported OSA from **Table 1** to those with AHI ≥ 5 events/h in **Table 2** (ie, assume that all those with reported OSA had AHI ≥ 5 events/h), the prevalence of any OSA would increase to 63.6% in males and to 43.6% in females. In addition, we used participant demographic and characteristics data of those who underwent a home sleep study to predict (impute) the prevalence of OSA in BHAS participants who did not have a sleep study (including those who reported OSA). Those participants not having a sleep study tended to have a higher alcohol intake and more often reported OSA. The latter was expected since participants with known OSA or its treatment were not offered overnight sleep monitoring. In addition, for those not having a sleep study, males had increased body weight and were more likely to be current smokers, and females weighed less and reported less daytime sleepiness than those having a sleep study. However, the inclusion of the imputed prevalence of OSA had little effect on the measured prevalence.

Apart from age and Berlin score, the features associated with having moderate-severe OSA differed between males (glasses of alcohol per week, daytime sleepiness score) and females (BMI, reduced tertiary education). Associations with severe OSA (vs no or less-severe OSA) also differed in males (BMI, alcohol intake, education level, Berlin questionnaire score) and females (Berlin questionnaire score).

Mild OSA syndrome was associated with sleepy driving and high risk of OSA on the Berlin questionnaire. Additional and different features were also associated with mild OSA syndrome in males (current smoking and lower levels of education) and females (increased age and increased BMI, in paid employment). Moderate-severe OSA syndrome correlated with increased BMI

Table 7—Comorbidities (adjusted for participant demographics, and adjusting for both participant demographics and lifestyle factors) associated with obstructive sleep apnea.

	n (%)				Adjusting for Patient Demographic Factors				Adjusting for Patient Demographic and Lifestyle Factors			
	Male		Female		Male		Female		Males		Females	
Comorbidities	AHI < 15 events/h	AHI ≥ 15 events/h	AHI < 15 events/h	AHI ≥ 15 events/h	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Hypertension*	373 (39.3)	140 (58.1)	483 (35.9)	78 (52.3)	1.814 (1.346–2.445)	< .0001	1.485 (1.04–2.121)	.0295	1.237 (0.89–1.718)	.2053	0.966 (0.658–1.417)	.8578
Stroke/TIA	22 (2.3)	11 (4.6)	21 (1.6)	2 (1.3)	1.599 (0.75–3.409)	.2241	0.712 (0.161–3.137)	.653	1.428 (0.654–3.121)	.3716	0.402 (0.084–1.917)	.2529
Coronary heart disease	58 (6.1)	23 (9.5)	24 (1.8)	2 (1.3)	1.284 (0.761–2.166)	.3498	0.631 (0.145–2.742)	.5386	1.171 (0.68–2.015)	.5688	0.371 (0.079–1.748)	.2102
Current depression	125 (13.2)	50 (20.7)	316 (23.5)	28 (18.8)	1.749 (1.201–2.547)	.0035	0.677 (0.434–1.054)	.0841	1.697 (1.153–2.496)	.0073	0.592 (0.376–0.933)	.0238
Cancer	126 (13.3)	34 (14.1)	193 (14.3)	33 (22.1)	0.91 (0.597–1.388)	.6626	1.396 (0.91–2.143)	.1268	0.991 (0.643–1.527)	.9679	1.366 (0.88–2.12)	.1643
Skin cancer	83 (8.7)	21 (8.7)	99 (7.4)	21 (14.1)	–	.753	1.803 (1.07–3.038)	.0267	1.008 (0.596–1.707)	.975	1.796 (1.048–3.077)	.033
Diabetes	51 (5.4)	19 (7.9)	53 (3.9)	14 (9.4)	1.159 (0.659, 2.036)	.6086	1.978 (1.048–3.73)	.0352	0.858 (0.466–1.58)	.6234	1.144 (0.577–2.267)	.7003

Odds ratios are for AHI ≥ 15 events/h vs < 15 events/h. *History of hypertension or elevated blood pressure on assessment; #skin cancer. AHI = apnea-hypopnea index, CI = confidence interval, OR = odds ratio, TIA = transient ischemic attack.

and high risk of OSA based on the Berlin questionnaire in both males and females.

The factors associated with OSA differed for males and females in this study. Sex differences in associations with OSA have been observed previously. A number of studies have consistently shown an increased prevalence of OSA in males compared with females, independent of age, BMI, and menopausal status.[36] These differences have been attributed to differences in upper airway structure/compliance,[37] ventilatory responses to stimuli,[38] and body fat distribution.[9] The increased prevalence of OSA in women following menopause also suggests hormonal effects.[32]

OSA may be associated with different presenting symptoms in males and females, with sleep disturbance and current depression reported more often in females with OSA.[35] As the present study shows, there is a distinction between sexes in prevalence of current depression (greater in females) and its association with OSA severity (positive in males and negative in females). A potential effect of this is that although the prevalence of OSA in males was approximately double that in females, the prevalence of depression in males and females with OSA was similar. It is possible, particularly where OSA is mild, that depressive symptoms, including disturbed sleep and daytime dysfunction, are more likely to be misattributed to clinical depression in females than males, given that other more specific symptomatology such as snoring and witnessed apneas are more prominent in men. Such misattribution may decrease as OSA becomes more severe/obvious, accounting for the negative association between OSA severity and apparent depression in females.

The relative uniformity of the population studied, particularly with regard to age and race, has the potential to limit the generalizability of some of the findings in the present study. This uniformity has been maintained over the course of the 3 studies of prevalence of OSA in this community. This is likely a strength for comparison of trends in prevalence, since we can conclude that factors other than age and race have accounted for the increase in prevalence of OSA. However, generalization to other populations must be undertaken with caution since racial factors[6,8,21] may influence the prevalence of OSA. Compared with the general Australian population in 2007,[39] the population in the Busselton Healthy Ageing Study is similar in regard to some potential risk factors and health outcomes associated with OSA (such as obesity, hypertension) but not others (less current cigarette smoking, more alcohol use). Many of these factors were included in statistical models examining associations with OSA in the present study. We cannot exclude, however, that the associations with OSA may differ between populations.

In conclusion, successive surveys of middle-aged populations from the same community demonstrate that the prevalence of OSA is high, has increased in males since 1995, but appears to have been stable in males and females between 2007 and 2010–2015. The features associated with OSA differ between males and females.

ABBREVIATIONS

AHI, apnea-hypopnea index
BHAS, Busselton Healthy Ageing Study
BMI, body mass index
CI, confidence interval
ESS, Epworth Sleepiness Scale
OR, odds ratio
OSA, obstructive sleep apnea

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