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# The Relationship between Functional Health Literacy and Obstructive Sleep Apnea and its Related Risk Factors and Comorbidities in a Population Cohort of Men

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**Study Objectives:** To examine the relationship between functional health literacy (FHL) and obstructive sleep apnea (OSA), its diagnosis, related risk factors, and comorbidities.

**Design:** Population cohort study.

**Setting:** Adelaide, South Australia, 2011-12.

**Participants:** 1,021 Men Androgen Inflammation Lifestyle Environment and Stress Study participants aged ≥ 40 years, of whom 627 were identified with OSA by self-report (n = 184 previously diagnosed) or with in-home polysomnography in 837 randomly selected participants without self-reported OSA (n = 443 previously undiagnosed).

**Interventions:** The Newest Vital Sign assessed FHL in 88% of participants. Full in-home unattended polysomnography (Embletta X100) was scored by 2007 AASM (alternative) criteria.

**Measurements and Results:** FHL was adequate in 75.3% (n = 122) of previously diagnosed and 68.3% (n = 261) of previously undiagnosed OSA. Not having a previous diagnosis was independently associated with inadequate FHL (odds ratio [OR]:2.84, 95% confidence interval [CI]:1.25-6.45) and workforce participation (OR = 2.04, 95%CI = 1.01-4.00), and inversely associated with previous snoring (OR = 0.48, 95%CI = 0.29-0.81), obesity (OR = 0.35, 95%CI = 0.15-0.81), and cardiovascular disease (OR = 0.45, 95%CI = 0.24-0.85).

In polysomnography participants, inadequate FHL was independently associated with previously undiagnosed OSA (OR = 2.43, 95%CI = 1.40-4.20). In undiagnosed men, less than adequate FHL was independently associated with sedentary lifestyle (OR = 2.42, 95%CI = 1.36-4.29), and depression (OR = 2.50, 95%CI = 1.23-5.09) and inadequate FHL was associated with current smoking (OR = 2.87, 95%CI = 1.21-6.84). The depression association was attenuated after additional adjustment for comorbidities and general health (OR = 2.04, 95%CI = 0.93-4.49, P = 0.076). In previously diagnosed OSA, less than adequate FHL was independently associated with cardiovascular disease (OR = 2.76, 95%CI = 1.09-7.01).

**Conclusions:** Limited functional health literacy was independently associated with obstructive sleep apnea (OSA), OSA diagnosis, lifestyle factors and comorbidities, highlighting the importance of developing and promoting national disease-specific health literacy policies.

**Keywords:** Health literacy, obstructive sleep apnea, diagnosis, cardiovascular disease, Newest Vital Sign, cohort study, depression, men

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## INTRODUCTION

Prevalence studies have shown that obstructive sleep apnea (OSA) is relatively common,[1-3] and three-quarters of OSA remains undiagnosed.[4] The problem of under-diagnosis has significant implications given that OSA is independently associated with incident hypertension, coronary syndromes, stroke and diabetes[5,6] and all-cause mortality.[7-9]

To date, no studies have examined the association between health literacy and sleep disorders, and Hackney et al.[10] speculate that health literacy is likely to impact upon constant positive airway pressure therapy adherence and the diagnosis and management of restless legs syndrome and insomnia. Health literacy is a broad multidimensional concept that adversely affects health outcomes via causal mechanisms such as the ability to understand medical information related to health care, disease prevention, and health promotion.[11] Functional Health literacy (FHL), identified with validated instruments including the Newest Vital Sign (NVS), is a more limited concept defined as the extent to which an individual can read, calculate and act on basic healthcare information (such as that entailed on prescription bottles, appointment slips, discharge instructions) in order to make informed health decisions.[12] Poor FHL is highly prevalent in developed countries, with data from the United States of America and Australia suggesting that approximately half of adults have less than adequate FHL.[13-15] Health literacy affects health system use/costs,[13,16,17] disease knowledge and self-management behaviors,[10,16,18] and health outcomes,[16,19] and is broadly related to health status.[16]

The aim of this study therefore was to investigate the relationship between FHL (as assessed with the NVS) and OSA, its diagnosis and related risk factors and comorbidities in men participating in The Men Androgen Inflammation Lifestyle Environment and Stress (MAILES) Study, a biomedical population cohort study of men aged 40 years and over.

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## METHODS

### Study Participants

The previously described MAILES Study[20] which aims to determine factors associated with diabetes and cardiovascular disease outcomes including OSA, consists of eligible male participants from 2 concurrent longitudinal biomedical cohorts, which are largely representative of the demographics in the State of South Australia: the Florey Adelaide Male Ageing Study (FAMAS)[21] and the North West Adelaide Health Study (NWAHS).[22] Most data for the current study was acquired in 2010-12, from follow-up assessments; however, self-reported snoring, snorting, and choking data were acquired in 2005-2007 (MAILES Stage 1). Both FAMAS and NWAHS used the same methodology for random population sampling, and biomedical assessment was conducted in 2 hospital-based clinics, using standardized and reproducible study protocols including administration of the Newest Vital Sign (NVS, see below), blood pressure measurement, anthropometry, and a fasting blood sample drawn for lipids and glucose. Body mass index (kg/m$^2$) was categorized according to international criteria: underweight/normal $\leq$ 24.9, overweight 25.0-29.9, and obesity: $\geq$ 30.0. Central obesity was identified using the measure of waist circumference (WC), defined as a WC $\geq$ 102 cm. A self-completed questionnaire collected detailed demographic information self-reported comorbidities, health-related quality of life by the SF-36, and risk factor information.

Diabetes was defined by self-report of a previous doctor diagnosis, a fasting plasma glucose $\geq$ 7.0 mmol/L, or glycated hemoglobin $\geq$ 6.5%. Nocturia was defined as voiding urine $\geq$ 2 times per night,[23] identified by Question 7 of the International Prostate Symptom Score ("Over the past month, how many times did you most typically get up to urinate from the time you went to bed at night until the time you got up in the morning?"). Depression was defined as a score > 12 on the Beck Depression Inventory[24] (for FAMAS males) or a score $\geq$ 21 on the Center for Epidemiological Studies Depression Scale (for NWAHS males). Hypertension was defined as systolic blood pressure $\geq$ 140 mm Hg and/or diastolic $\geq$ 90 mm Hg, or treatment with antihypertensive medications. Cardiovascular disease was defined as self-reported myocardial infarction, angina, stroke, or transient ischemic attack. General health was measured utilizing Question 1 of the MOS Short-Form 36 Health Survey.[25]

No selection bias was detected at baseline,[26] but due to participant attrition, the participants at follow-up are slightly better educated and self-report better general health than the general population.[27]

### Polysomnography and Definition of OSA

MAILES study participants completed a Computer-Assisted Telephone Interview (CATI) survey in August 2010 (n = 1,629). Figure S1 in the supplemental material shows the flow of participants through the study. This survey included questions regarding demographical, biographical and comorbidities information. Subjects reporting "yes" to "Have you ever been diagnosed with obstructive sleep apnea with a sleep study?" (n = 184) were considered to have previously diagnosed OSA and were not asked to undertake a further sleep study. The subjects reporting "no" to the same question were invited to undergo a sleep study, with 75.2% (1,087 out of 1,445) agreeing. Of these, a random sample (n = 857) undertook an 8-channel in-home unattended polysomnography (PSG) (Embletta X100, Embla Systems, Colorado), the equipment for which was set up and attached by trained staff. The PSG measured EEG, EOG, EMG, nasal pressure, thoracic and abdominal effort, oximetry, body position, and limb movements. Failed PSGs were repeated where possible. The Epworth Sleepiness Scale (ESS)[28] was administered, and measures of height, weight, and WC were also taken. Any necessary clinical follow-up was coordinated by a physician investigator, the results were made available to participants and, if the participant consented, results were sent to their primary care practitioner.

All PSGs were manually scored by a single experienced sleep technician, according to the 2007 American Academy of Sleep Medicine (AASM) (alternative) criteria.[29] Apneas were defined as cessations of nasal flow lasting $\geq$ 10 seconds. Hypopneas were defined as > 50% decrease in nasal flow (or in both thoracic and abdominal excursions) and associated with either $\geq$ 3% oxygen desaturation or an EEG arousal. An apnea-hypopnea index (AHI) $\geq$ 10 events per hour of sleep by these criteria has been shown to be approximately equivalent to an AHI of at least 5/h of sleep used in earlier studies[3,30] and so was the definition used in this study.

### Newest Vital Sign (NVS)

The Newest Vital Sign (NVS) is a validated screening tool used to identify individuals at risk of limited functional health literacy.[31,32] It can be administered in 3 minutes and was designed for use in primary care. The NVS asks patients to read and interpret a standardized nutrition label derived from an ice cream container, about which they are asked 6 standardized questions. There is only one correct answer per question resulting in a score ranging from 0 to 6. A score of 4-6 almost always indicates adequate FHL ("adequate"), while a score of 2-3 indicates the possibility of limited FHL ("at risk"), and a score of 0-1 indicates $\geq$ 50% likelihood of limited FHL ("inadequate"). A score of 0-3, which indicates inadequate or at risk FHL, is described in this article as "less than adequate."[31] A standardized approach to the administration of the NVS was taken by the 2 clinic staff, and coaching was not permitted.

### Statistical Analysis

Data were analyzed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA). Univariate associations of FHL with demographics, risk factors, and comorbidities were determined using the $\chi^2$ test. To determine factors independently associated with not being diagnosed with OSA in the all OSA population (consisting of the previously diagnosed and previously undiagnosed), a multivariable logistic regression model was constructed containing all variables found to have a univariate association of $\chi^2$ P-value $\leq$ 0.25, including age, income and education, BMI, plus daytime sleepiness, which is traditionally believed to be associated with OSA despite a P-value > 0.25 in our cohort. Only previous snoring was included in the model as a measure of previous symptoms, because other symptomatology largely identified the same men.

In the men who undertook polysomnography, the logistic regression model assessing the association of FHL with

undiagnosed OSA was adjusted for age, income, education, and BMI. In men with previously undiagnosed OSA (Table 3) and previously diagnosed OSA (Table 4), the logistic regression models determining associations of less than adequate FHL with OSA-related risk factors and comorbidities (which included BMI) were adjusted for age, income, and education.

All protocols herein were approved by the Research Ethics Committees of the Royal Adelaide Hospital and the North West Adelaide Health Service. All participants gave written informed consent.

## RESULTS

Complete NVS data were available in 162 of the 184 participants (88.0%) with a previous diagnosis of OSA. The NVS was completed in 740 of 837 participants who undertook a PSG (88.4%). Of these 740 men, an AHI ≥ 10 was demonstrated in 382 (51.6%) who were termed "previously undiagnosed OSA." FHL was adequate in 75.3% (n = 122) of previously diagnosed and 68.3% (n = 261) of previously undiagnosed OSA.

### Factors Associated with Previously Undiagnosed OSA

Table 1 shows the FHL, demographic and biomedical characteristics of men with OSA in relation to diagnosis of their OSA. In univariate analyses, compared to the men who self-reported a previous diagnosis of OSA, men with OSA identified in this study by PSG (i.e. previously undiagnosed) were significantly more likely to be younger, report higher annual income, be workforce participants, and were less likely to report previous snoring or have comorbidities including obesity, cardiovascular disease (CVD), diabetes, and depression. These associations largely persisted in logistic regression analysis (except age, income, and depression), and men with previously undiagnosed OSA were also more likely to have inadequate FHL.

It was unclear what criteria were used to diagnose the men who self-reported OSA, and in order to account for a possible diagnostic bias of a more severe OSA presentation in these men, we also performed the above analysis comparing moderate-to-severe previously undiagnosed OSA (AHI ≥ 20 events/h) with previously diagnosed OSA (Table S1, supplemental material). In the logistic regression model, men with moderate-to-severe previously undiagnosed OSA had an increased likelihood of having inadequate FHL (OR 2.41, 95% CI 0.97-6.00), though this was of borderline significance (P = 0.059) and be significantly less likely to report previous snoring and have diabetes.

### Relationship between FHL and Previously Undiagnosed OSA

In the population of men who underwent a PSG, compared to men with adequate FHL, those with inadequate FHL were significantly more likely

**Table 1**—Functional health literacy, demographic and biomedical characteristics [% (n)] of men with OSA in relation to diagnosis, and adjusted odds ratios* of factors associated with previously undiagnosed OSA

| Participant Characteristic | Previously diagnosed OSA (n = 162) | Previously undiagnosed OSA (n = 382) | $\chi^2$ P-value | Odds ratio* (95% CI) |
|---|---|---|---|---|
| FHL | | | 0.252 | |
| Inadequate | 11.1 (18) | 15.2 (58) | | **2.84 (1.25-6.45)** |
| At risk | 13.6 (22) | 16.5 (63) | | 1.71 (0.86-3.39) |
| Adequate | 75.3 (122) | 68.3 (261) | | 1.00 |
| Age, years | | | 0.045 | |
| < 50 | 10.5 (17) | 17.5 (67) | | 1.00 |
| 50-59 | 27.2 (44) | 29.8 (114) | | 0.59 (0.25-1.39) |
| 60-69 | 38.9 (63) | 28.3 (108) | | 0.51 (0.20-1.32) |
| ≥ 70 | 23.5 (38) | 24.3 (93) | | 0.74 (0.24-2.28) |
| Annual household income | | | 0.012 | |
| < $40,000 | 46.2 (74) | 33.9 (129) | | 0.70 (0.30-1.60) |
| $40,000-$79,000 | 32.5 (52) | 32.9 (125) | | 0.86 (0.43-1.74) |
| ≥ $80,000 | 16.9 (27) | 28.9 (110) | | 1.00 |
| Not stated | 4.4 (7) | 4.2 (16) | | 0.53 (0.14-2.04) |
| Financial stress | | | 0.142 | |
| Under financial stress | 27.2 (44) | 21.7 (83) | | 1.13 (0.49-2.61) |
| Breaks even | 60.5 (98) | 59.9 (229) | | 1.12 (0.56-2.25) |
| Saves a lot | 12.3 (20) | 18.3 (70) | | 1.00 |
| Education | | | 0.415 | |
| High School or Less | 38.3 (62) | 31.9 (122) | | 1.57 (0.69-3.57) |
| Trade or Apprenticeship | 29.6 (48) | 29.8 (114) | | 2.24 (0.96-5.23) |
| Certificate or Diploma | 21.0 (34) | 26.7 (102) | | **2.51 (1.06-5.97)** |
| Bachelor or Higher | 11.1 (18) | 11.5 (44) | | 1.00 |
| Workforce participation | | | 0.001 | |
| Yes | 40.7 (66) | 57.1 (218) | | **2.04 (1.00-4.00)** |
| No | 59.3 (96) | 42.9 (164) | | 1.00 |
| Marital status | | | 0.524 | |
| Not married or de facto | 25.3 (41) | 22.8 (87) | | – |
| Married or de facto | 74.7 (121) | 77.2 (295) | | – |
| Body mass index, kg/m$^2$ | | | < 0.001 | |
| < 25.0 | 6.8 (11) | 17.3 (66) | | 1.00 |
| 25.0-29.9 | 34.6 (56) | 42.4 (162) | | 0.63 (0.27-1.46) |
| ≥ 30.0 | 58.6 (95) | 40.3 (154) | | **0.35 (0.15-0.81)** |
| Cardiovascular disease | | | 0.005 | |
| No | 79.6 (129) | 88.7 (339) | | 1.00 |
| Yes | 20.4 (33) | 11.3 (43) | | **0.45 (0.24-0.85)** |
| Hypertension | | | 0.949 | |
| No | 38.5 (62) | 38.2 (146) | | – |
| Yes | 61.5 (99) | 61.8 (236) | | – |
| Diabetes | | | < 0.001 | |
| No | 69.1 (112) | 73.8 (316) | | 1.00 |
| Yes | 30.9 (50) | 17.3 (66) | | 0.60 (0.35-1.04) |
| Depression | | | 0.014 | |
| No | 77.8 (119) | 86.5 (314) | | 1.00 |
| Yes | 22.2 (34) | 13.5 (49) | | 0.85 (0.43-1.67) |
| Previous snoring | | | 0.001 | |
| Never or rarely | 37.4 (46) | 57.3 (189) | | 1.00 |
| Yes | 52.8 (65) | 35.8 (118) | | **0.48 (0.29-0.81)** |
| Don't know/refused | 9.8 (12) | 7.0 (23) | | 0.52 (0.22-1.23) |
| Previous snorting | | | < 0.001 | |
| Never or rarely | 44.7 (55) | 64.5 (213) | | – |
| Yes | 43.9 (54) | 23.3 (77) | | – |
| Don't know/refused | 11.4 (14) | 12.1 (40) | | – |
| Previous choking | | | < 0.001 | |
| Never or rarely | 59.7 (74) | 84.8 (278) | | – |
| Yes | 22.6 (28) | 4.9 (16) | | – |
| Don't know/refused | 17.7 (22) | 10.4 (34) | | – |
| Daytime sleepiness | | | 0.593 | |
| No or sometimes | 54.3 (88) | 56.8 (217) | | 1.00 |
| Yes | 45.7 (74) | 43.2 (165) | | 1.05 (0.64-1.73) |
| Waking frequently at night | | | 0.165 | |
| No or sometimes | 54.3 (88) | 60.7 (232) | | 1.00 |
| Yes | 45.7 (74) | 39.3 (150) | | 0.78 (0.48-1.27) |

*Odds ratio for previously undiagnosed OSA, calculated using a multivariable logistic model containing variables with $\chi^2$ P-value ≤ 0.25, plus daytime sleepiness and excluding snorting and choking. Bolded odds ratios are statistically significant. FHL, functional health literacy; OSA, obstructive sleep apnea.

**Table 2**—Association between functional health literacy and previously undiagnosed OSA in men undergoing polysomnography (n = 740), and adjusted odds ratios* for undiagnosed OSA

| Functional Health Literacy | No OSA, % (n) | OSA, % (n) | $\chi^2$ P-value | Adjusted Odds Ratio* (95% CI) |
|---|---|---|---|---|
| Inadequate | 32.6 (28) | 67.4 (58) | | 2.43 (1.40-4.20) |
| At-risk | 44.2 (50) | 55.8 (63) | < 0.05 | 1.31 (0.83-2.07) |
| Adequate | 51.8 (280) | 48.2 (261) | | 1.00 |

*Odds ratios adjusted for age, income, education, and body mass index. OSA, obstructive sleep apnea.

to have previously undiagnosed OSA, and this association persisted after adjusting for age, income, education, and BMI (Table 2). No significant association between FHL and OSA severity was observed (P = 0.79).

### Factors Associated with Less than Adequate FHL in Previously Undiagnosed OSA

Table 3 shows the relationship between FHL and OSA-related comorbidities and risk factors in the men with OSA identified by PSG (previously undiagnosed). There were significant univariate associations between FHL and CVD, hypertension, total cholesterol, sedentary lifestyle, diabetes, nocturia, and general health. In the adjusted models, associations persisted with depression, poor to fair general health, and sedentary lifestyle, and borderline associations were observed with hypertension, current smoking, lower WC, and lower BMI levels. In separate analyses of factors associated with inadequate FHL (data not shown), inadequate FHL (i.e., NVS score of 0-1) was significantly associated with current smoking (OR = 2.87, 95% CI 1.21-6.84), and lower WC (OR 0.52, 95% CI 0.27-0.99).

In the additional logistic regression analyses of depression (data not shown), the significant relationship with less than adequate FHL persisted after additional adjustment for marital status and comorbidities including obesity, CVD, and diabetes (P = 0.016, OR = 2.45, 95% CI 1.18-5.09). However, further additional adjustment for general health was made to account for residual confounding by other health factors. In this final model, the association between less than adequate FHL and depression was attenuated, and of borderline significance (P = 0.076).

### Factors Associated with Less than Adequate FHL in Men with a Prior Diagnosis of OSA

Table 4 shows the relationship between FHL and OSA-related comorbidities and risk factors in previously diagnosed OSA. Univariate associations were found between FHL and presence of CVD, hypertension, and general health. After adjusting for age, income, and education, the relationship between less than adequate FHL and CVD persisted. The adjusted odds ratios for the associations between less than adequate FHL and hypertension, sedentary lifestyle were elevated, but the associations were not statistically significant.

## DISCUSSION

Our results suggest that in men with OSA, those with inadequate functional health literacy are likely to remain undiagnosed. This is the first study to describe this relationship and confirms previous studies that have implicated health literacy as a determinant of health status.[16,19] Undiagnosed men are almost three times as likely to have inadequate functional health literacy as diagnosed men, even after adjusting for demographics, symptomatology, and comorbidities. Health literacy is therefore an important determinant in OSA diagnosis. A possible explanation for this may be that the significance of OSA symptoms is not recognized by patients, bed partners, or clinicians. OSA is a unique disease in that bed partners commonly drive the referral and consultation process, and so the health literacy of bed partners may be important to investigate in future research. Snoring is arguably the most important symptom to recognize in patients at risk of sleep apnea, as other common symptoms including daytime sleepiness are not reported in a large proportion of patients.[33] As 36% of the undiagnosed men (and 40% of the men with moderate-to-severe undiagnosed OSA) had reported significant snoring at least five years before the diagnosis was made by PSG in this study, it seems likely that the issue of snoring does not get addressed. Furthermore, there is likely to be a lower level of clinical suspicion in men with lower waist circumference and BMI, resulting in a sleep history not being pursued. Therefore a connection between their sleep disordered breathing and other health problems may not be made. If those men also concurrently have inadequate FHL, then they may not recognize the significance of their symptoms and/or not adequately articulate their symptoms or concerns to their primary care practitioners. Their OSA would have thereby remained undiagnosed until they were randomly sampled to undergo PSG for our study. This could explain the association between inadequate FHL and lower waist circumference found in our study, and is supported by the lack of significant association between FHL and WC and BMI in the previously diagnosed men. Public education initiatives and further professional development for clinicians to increase knowledge of the significance of snoring should be investigated, especially given the low sensitivity of the current clinical approach[34] and the low uptake of OSA screening tools such as the long-standing Berlin questionnaire[35] in primary care. It is unclear whether current screening tools such as the Berlin[35] and OSA50[36] questionnaires are as clinically useful in people with low FHL as in others, and research on this should be encouraged.

Low FHL was independently associated with undiagnosed OSA, and also with sedentary lifestyle and current smoking, factors related to the development of OSA.[37] There is evidence that people with low health literacy are less likely to adopt lifestyle changes,[38] although it is unclear whether this applies specifically to people with OSA. Our results suggest that education regarding lifestyle modification among people with OSA needs to be formulated with health literacy in mind, with an emphasis on clarity of communication. Although there have been recent improvements, much written information for consumers regarding sleep apnea is beyond the easy comprehension of the majority of adults, and further improvements must still be made.[39] Recognition also needs to be given to the

problem of low income, often concurrent with FHL limitations, and the effect this can have on the management of OSA.[40] While there is a clear gradient of poorer health literacy occurring with decreasing social advantage,[14] we have previously shown that even among those with a bachelor degree or higher, around 20% were at risk of limited FHL.[13] Thus educational level is a poor proxy measure of health literacy and will misclassify a substantial proportion of people as health literate/illiterate[14] and this also needs consideration in the clinical management of OSA when taken together with evidence suggesting that clinicians may overestimate patients' literacy skills.[41]

We found that less than adequate FHL was associated with depression in men with undiagnosed OSA when adjusted for demographics, marital status, and comorbidities, but not after also adjusting for general health, a similar result to that previously found in an elderly population.[42] However, we also found that less than adequate FHL is negatively associated with general health. As such, the direction of causality, if any exists, between the three factors of FHL, depression, and general health is unclear. Nonetheless, depression is highly prevalent in OSA patients,[37] and there is some, albeit limited, evidence that poor health literacy adversely affects depression management,[43] and is correctable by a health literacy intervention.[44]

In the men with diagnosed OSA, we found an independent association between less than adequate FHL and cardiovascular disease. Health literacy therefore has management implications given that cardiovascular disease is a major comorbidity of obstructive sleep apnea[8,9] and is also a major contributor to all-cause mortality seen in OSA patients.[7,8] While there were no other significant associations found in the men with diagnosed OSA, the low sample size (n = 162) of previously diagnosed men may have contributed to a possible type II error. It is unclear whether the elevated, but not statistically significant, odds ratios for the associations between FHL and hypertension, sedentary lifestyle, and depression represent true clinical associations in men with OSA. Further studies with larger sample sizes are required to determine this.

**Table 3**—FHL [% (n)] in relation to comorbidities and risk factors in men with previously undiagnosed OSA (n = 382), with adjusted odds ratios† for less than adequate levels of FHL

| | Functional Health Literacy (% [n]) | | | |
|---|---|---|---|---|
| **Risk Factor or Comorbidity** | **Inadequate** | **At risk** | **Adequate** | **Adjusted Odds Ratio (95% CI)** |
| Adiposity | | | | |
| Body mass index, kg/m$^2$ | | | | |
| < 25.0 | 21.2 (14) | 18.2 (12) | 60.6 (40) | 1.00 |
| ≥ 25.0 | 13.9 (44) | 16.1 (51) | 69.9 (221) | 0.57 (0.30-1.07) |
| Waist circumference, cm | | | | |
| < 102 | 17.3 (35) | 16.8 (34) | 65.8 (133) | 1.00 |
| ≥ 102 | 12.8 (23) | 16.1 (29) | 71.1 (128) | 0.63 (0.38-1.03) |
| Physical activity* | | | | |
| Active | 13.5 (39) | 14.9 (43) | 71.5 (206) | 1.00 |
| Sedentary | 20.2 (18) | 22.5 (20) | 57.3 (51) | **2.42 (1.36-4.29)** |
| Smoking | | | | |
| Never/former smoker | 13.7 (44) | 17.4 (56) | 68.9 (222) | 1.00 |
| Current smoker | 22.8 (13) | 12.3 (7) | 64.9 (37) | 1.95 (0.95-4.00) |
| Alcohol risk | | | | |
| None or low risk | 16.0 (56) | 16.0 (56) | 68.1 (239) | 1.00 |
| Medium to high risk | 6.7 (2) | 20.0 (6) | 73.3 (22) | 0.78 (0.30-2.00) |
| Cardiovascular disease | | | | |
| No | 14.5 (49) | 14.7 (50) | 70.8 (240) | 1.00 |
| Yes | 20.9 (9) | 30.2 (13) | 48.8 (21) | 1.40 (0.68-2.89) |
| Hypertension* | | | | |
| No | 11.6 (17) | 9.6 (14) | 78.8 (115) | 1.00 |
| Yes | 17.4 (41) | 20.8 (49) | 61.9 (146) | 1.62 (0.95-2.76) |
| Cholesterol, mmol/L | | | | |
| Total* | | | | |
| < 5.5 | 17.2 (40) | 20.3 (47) | 62.5 (145) | 1.00 |
| ≥ 5.5 | 12.0 (18) | 10.7 (16) | 77.3 (116) | 0.69 (0.41-1.16) |
| Low-density lipoprotein | | | | |
| < 4.0 | 15.5 (48) | 18.4 (57) | 66.1 (205) | 1.00 |
| ≥ 4.0 | 14.3 (9) | 7.9 (5) | 77.8 (49) | 0.78 (0.39-1.57) |
| Diabetes* | | | | |
| No | 13.9 (44) | 14.6 (46) | 71.5 (226) | 1.00 |
| Yes | 21.2 (14) | 25.8 (17) | 53.0 (35) | 1.21 (0.65-2.25) |
| Depression | | | | |
| No | 14.3 (45) | 15.3 (48) | 70.4 (221) | 1.00 |
| Yes | 20.4 (10) | 24.5 (12) | 55.1 (27) | **2.50 (1.23-5.09)** |
| Epworth Sleepiness Scale ≥ 11 | | | | |
| No | 15.4 (49) | 15.7 (50) | 69.0 (220) | 1.00 |
| Yes | 15.5 (9) | 17.9 (10) | 66.1 (37) | 1.14 (0.58-2.22) |
| Nocturia* | | | | |
| No | 12.2 (34) | 14.7 (41) | 73.1 (204) | 1.00 |
| Yes | 23.3 (24) | 21.4 (22) | 55.3 (57) | 1.34 (0.78-2.29) |
| General health* | | | | |
| Good or excellent | 13.8 (44) | 14.8 (47) | 71.4 (227) | 1.00 |
| Fair or poor | 21.3 (13) | 26.2 (16) | 52.5 (32) | **2.97 (1.51-5.84)** |

*$\chi^2$ test P-value < 0.05. †Odds ratios adjusted for age, income, and education. Bolded odds ratios are statistically significant. FHL, functional health literacy; OSA, obstructive sleep apnea.

Our study was limited to men and therefore the results of our study cannot be generalized to women. Another possible limitation of this study may have been the chosen measure of functional health literacy. Although the NVS is a validated measure of FHL,[31,45] it tends to identify more people with less than adequate FHL when compared to the Test of Functional Health Literacy in Adults (TOFHLA).[46] However, commentators have previously suggested that none of the current brief measures of health literacy test for all aspects of health literacy in a comprehensive manner,[47,48] and so it is unclear which health literacy measure is superior to the other in that regard. Furthermore,

**Table 4**—Functional health literacy [FHL, %, (n)] in relation to comorbidities and risk factors in previously diagnosed OSA (n = 162), and adjusted odds ratios† for less than adequate levels of FHL

| | Functional Health Literacy (% [n]) | | | Odds |
|---|---|---|---|---|
| **Comorbidity or Risk Factor** | **Inadequate** | **At risk** | **Adequate** | **Ratio (95% CI)** |
| Adiposity | | | | |
| Body mass index, kg/m$^2$ | | | | |
| < 25.0 | 0.0 (0) | 27.3 (3) | 72.7 (8) | 1.00 |
| ≥ 25.0 | 11.9 (18) | 12.6 (19) | 75.5 (114) | 0.68 (0.14-3.38) |
| Waist circumference, cm | | | | |
| < 102 | 13.1 (8) | 18.0 (11) | 68.9 (42) | 1.00 |
| ≥ 102 | 9.9 (10) | 10.9 (11) | 79.2 (80) | 0.50 (0.22-1.14) |
| Physical activity* | | | | |
| Active | 11.2 (14) | 12.8 (16) | 76.0 (95) | 1.00 |
| Sedentary | 12.5 (4) | 18.8 (6) | 68.8 (22) | 2.28 (0.79-6.52) |
| Smoking | | | | |
| Never/former smoker | 10.7 (15) | 13.6 (19) | 75.7 (106) | 1.00 |
| Current smoker | 15.8 (3) | 10.5 (2) | 73.7 (14) | 0.95 (0.26-3.52) |
| Alcohol risk | | | | |
| No or low risk | 11.8 (18) | 13.2 (20) | 75.0 (114) | 1.00 |
| Medium to high risk | 0.0 (0) | 20.0 (2) | 80.0 (8) | 0.81 (0.14-4.60) |
| Cardiovascular disease | | | | |
| No | 8.5 (11) | 10.1 (13) | 81.4 (105) | 1.00 |
| Yes | 21.2 (7) | 27.3 (9) | 51.5 (17) | **2.76 (1.09-7.01)** |
| Hypertension* | | | | |
| No | 6.5 (4) | 6.5 (4) | 87.1 (54) | 1.00 |
| Yes | 13.1 (13) | 18.2 (18) | 68.7 (68) | 1.94 (0.73-5.16) |
| Cholesterol, mmol/L | | | | |
| Total* | | | | |
| < 5.5 | 12.7 (15) | 14.4 (17) | 72.9 (86) | 1.00 |
| ≥ 5.5 | 6.8 (3) | 11.4 (5) | 81.8 (36) | 0.81 (0.30-2.17) |
| Low-density lipoprotein | | | | |
| < 4.0 | 11.4 (16) | 14.3 (20) | 74.3 (104) | 1.00 |
| ≥ 4.0 | 0.0 (0) | 11.8 (2) | 88.2 (15) | 0.52 (0.10-2.79) |
| Diabetes* | | | | |
| No | 10.7 (12) | 14.3 (16) | 75.0 (84) | 1.00 |
| Yes | 12.0 (6) | 12.0 (6) | 76.0 (38) | 0.61 (0.25-1.48) |
| Depression | | | | |
| No | 10.1 (12) | 12.6 (15) | 77.3 (92) | 1.00 |
| Yes | 5.9 (2) | 20.6 (7) | 73.5 (25) | 2.16 (0.76-6.17) |
| Nocturia* | | | | |
| No | 10.8 (12) | 9.9 (11) | 79.3 (88) | 1.00 |
| Yes | 11.8 (6) | 21.6 (11) | 66.7 (34) | 1.78 (0.77-4.13) |
| General health* | | | | |
| Good or excellent | 14.3 (15) | 9.5 (10) | 76.2 (80) | 1.00 |
| Fair or poor | 5.5 (3) | 21.8 (12) | 72.7 (40) | 1.19 (0.50-2.85) |

*$\chi^2$ test P-value < 0.05. †Odds ratios adjusted for age, income, and education. Bolded odds ratio is statistically significant. FHL, functional health literacy; OSA, obstructive sleep apnea.

we have previously shown[13] that the NVS identifies a similar proportion of the general population with inadequate FHL as the much longer tools used in international literacy comparison studies such as the Adult Literacy and Life Skills Survey.[14] In addition, the NVS can be administered in three minutes,[31] and a previous study found over 98% of patients agreed to take the NVS during a routine visit, without any significant adverse effect on patient satisfaction.[49]

The definition of OSA used in the study may also have been a possible limitation. Our definition of OSA as AHI ≥ 10 events/hour of sleep by the 2007 AASM (alternative) criteria is approximately equivalent to AHI ≥ 5[30] used in earlier studies,[3] and generated a prevalence consistent with the significant increases in modeled prevalence estimates recently reported by Peppard et al.,[1] but did not consider whether participants were symptomatic. Furthermore, we did not know what criteria were used by clinicians for the previously diagnosed cases of OSA in our sample. However, our sensitivity analysis utilizing the higher cut-off of AHI ≥ 20 in an attempt to account for a possible diagnostic bias of a more severe OSA presentation in the previously diagnosed men yielded similar results, suggesting the findings are robust. Thus, FHL limitations are likely to be contributing to not being diagnosed with moderate to severe OSA in men despite their high AHI and snoring history in 40% and sleepiness in 47%, although they are without related comorbidity (such as diabetes).

In conclusion, we have demonstrated an independent association between poor functional health literacy and OSA, together with its associated risk factors and comorbidities. The prevalence of obesity, particularly severe obesity, is increasing,[50] and is likely to be accompanied by an increase in the prevalence of OSA.[51] Our data highlight the importance of public health policy initiatives that aim to increase public awareness of the significance of OSA and its symptoms such as snoring.[52-54] Our findings also indicate the need for clinicians to undertake an adequate sleep history using a "universal precautions" approach, with clear and simple communication that avoids complex jargon.

## DISCLOSURE STATEMENT

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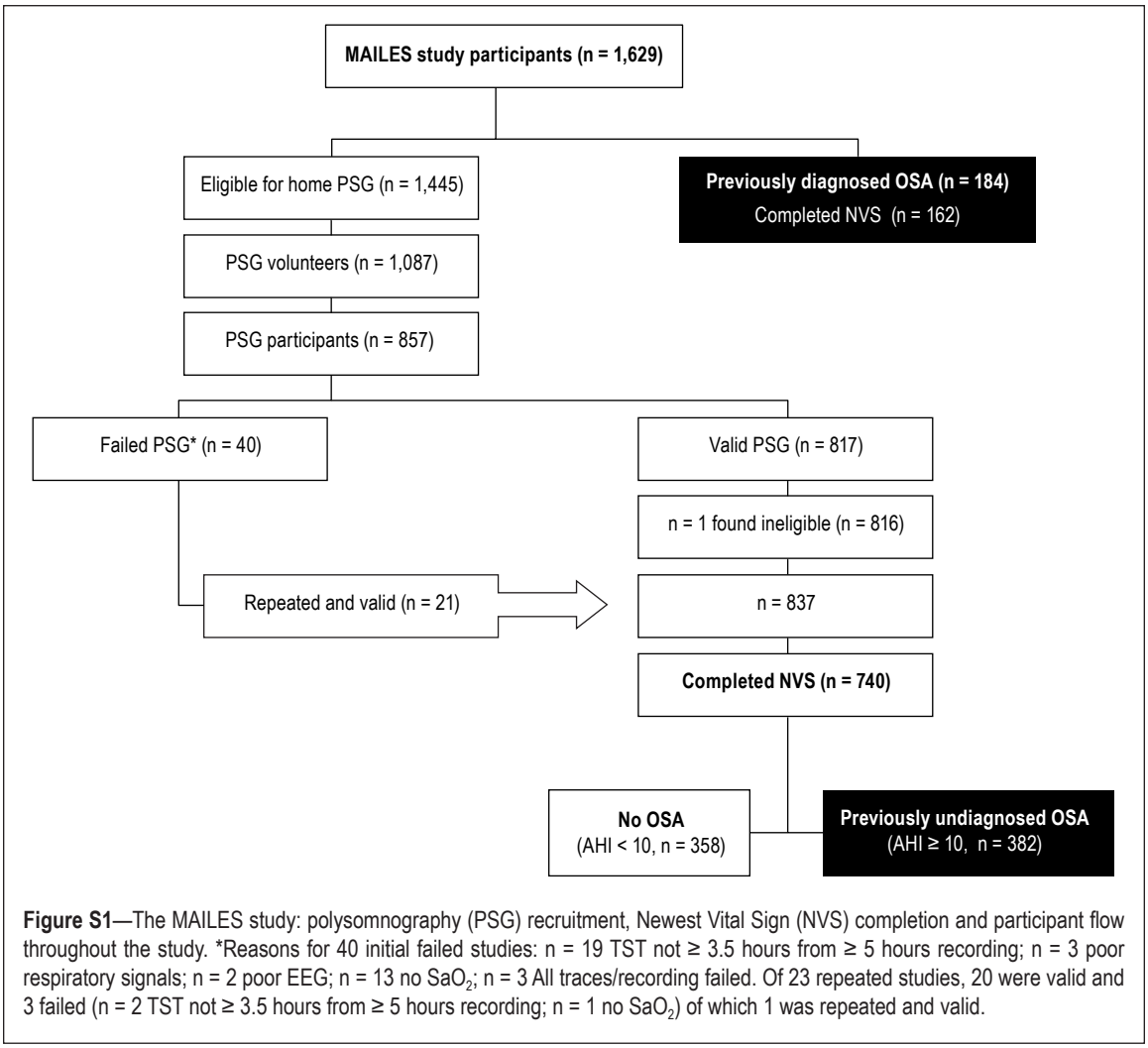


**Figure S1**—The MAILES study: polysomnography (PSG) recruitment, Newest Vital Sign (NVS) completion and participant flow throughout the study. *Reasons for 40 initial failed studies: n = 19 TST not ≥ 3.5 hours from ≥ 5 hours recording; n = 3 poor respiratory signals; n = 2 poor EEG; n = 13 no $SaO_2$; n = 3 All traces/recording failed. Of 23 repeated studies, 20 were valid and 3 failed (n = 2 TST not ≥ 3.5 hours from ≥ 5 hours recording; n = 1 no $SaO_2$) of which 1 was repeated and valid.

**Table S1**—Functional health literacy (FHL), demographic and biomedical characteristics (% [n]) of men with obstructive sleep apnea (OSA) in relation to diagnosis, and adjusted odds ratios* of factors associated with moderate-to-severe previously undiagnosed OSA (AHI ≥ 20 events/h)

| Demographic, Comorbidity or Symptom | Previously diagnosed OSA (n = 162) | Previously undiagnosed moderate-to-severe OSA (n = 184) | $\chi^2$ P-value | Odds ratio* (95% CI) |
|---|---|---|---|---|
| FHL | | | 0.331 | |
| Inadequate | 11.1 (18) | 15.8 (29) | | 2.41 (0.97-6.00) |
| At risk | 13.6 (22) | 15.8 (29) | | 1.54 (0.72-3.30) |
| Adequate | 75.3 (122) | 68.5 (125) | | 1.00 |
| Age | | | 0.440 | |
| < 50 | 10.5 (17) | 14.7 (27) | | 1.00 |
| 50-59 | 27.2 (44) | 29.3 (54) | | 0.61 (0.23-1.60) |
| 60-69 | 38.9 (63) | 31.5 (58) | | 0.57 (0.20-1.63) |
| ≥ 70 | 23.5 (38) | 24.5 (45) | | 0.76 (0.21-2.71) |
| Income | | | 0.085 | |
| < $40,000 | 46.2 (74) | 36.1 (66) | | 0.72 (0.27-1.94) |
| $40,000-$79,000 | 32.5 (52) | 33.3 (61) | | 0.97 (0.44-2.13) |
| ≥ $80,000 | 16.9 (27) | 27.3 (50) | | 1.00 |
| Not stated | 4.4 (7) | 3.3 (6) | | 0.42 (0.08-2.30) |
| Financial stress | | | 0.212 | |
| Under financial stress | 27.2 (44) | 20.1 (37) | | 0.92 (0.35-2.38) |
| Breaks even | 60.5 (98) | 63.0 (116) | | 1.12 (0.52-2.45) |
| Saves a lot | 12.3 (20) | 16.8 (31) | | 1.00 |
| Education | | | 0.377 | |
| High School or Less | 38.3 (62) | 32.1 (59) | | 1.58 (0.61-4.10) |
| Trade or Apprenticeship | 29.6 (48) | 30.4 (56) | | 2.08 (0.79-5.52) |
| Certificate or Diploma | 21.0 (34) | 28.3 (52) | | **2.72 (1.00-7.41)** |
| Bachelor or Higher | 11.1 (18) | 9.2 (17) | | 1.00 |
| Workforce participation | | | 0.043 | |
| Yes | 40.7 (66) | 51.6 (95) | | 1.00 |
| No | 59.3 (96) | 48.4 (89) | | 0.66 (0.29-1.52) |
| Marital status | | | 0.589 | |
| Not married or de facto | 25.3 (41) | 22.8 (42) | | – |
| Married or de facto | 74.7 (121) | 77.2 (142) | | – |
| Body mass index, kg/m$^2$ | | | 0.092 | |
| < 25.0 | 6.8 (11) | 12.5 (23) | | 1.00 |
| 25.0-29.9 | 34.6 (56) | 38.6 (71) | | 0.79 (0.30-2.11) |
| ≥ 30.0 | 58.6 (95) | 48.9 (90) | | 0.67 (0.26-1.76) |
| Cardiovascular disease | | | 0.092 | |
| No | 79.6 (129) | 86.4 (159) | | 1.00 |
| Yes | 20.4 (33) | 13.6 (25) | | **0.58 (0.29-1.18)** |
| Hypertension | | | 0.253 | |
| No | 38.5 (62) | 32.6 (60) | | – |
| Yes | 61.5 (99) | 67.4 (124) | | – |
| Diabetes | | | 0.007 | |
| No | 69.1 (112) | 81.5 (150) | | 1.00 |
| Yes | 30.9 (50) | 18.5 (34) | | 0.53 (0.28-0.99) |
| Depression | | | 0.044 | |
| No | 77.8 (119) | 86.3 (151) | | 1.00 |
| Yes | 22.2 (34) | 13.7 (24) | | 0.87 (0.41-1.87) |
| Previous snoring | | | 0.019 | |
| Never or rarely | 37.4 (46) | 54.0 (88) | | 1.00 |
| Yes | 52.8 (65) | 39.9 (65) | | **0.52 (0.29-0.92)** |
| Don't know/refused | 9.8 (12) | 6.1 (10) | | 0.46 (0.17-1.27) |
| Previous snorting | | | 0.002 | |
| Never or rarely | 44.7 (55) | 63.2 (103) | | – |
| Yes | 43.9 (54) | 24.5 (40) | | – |
| Don't know/refused | 11.4 (14) | 12.3 (20) | | – |
| Previous choking | | | < 0.001 | |
| Never or rarely | 59.7 (74) | 85.9 (140) | | – |
| Yes | 22.6 (28) | 4.3 (7) | | – |
| Don't know/refused | 17.7 (22) | 9.8 (16) | | – |
| Daytime sleepiness | | | 0.765 | |
| No or sometimes | 54.3 (88) | 52.7 (97) | | 1.00 |
| Yes | 45.7 (74) | 47.3 (87) | | 1.14 (0.66-1.98) |
| Waking up frequently at night | | | 0.165 | |
| No or sometimes | 54.3 (88) | 58.7 (108) | | 1.00 |
| Yes | 45.7 (74) | 41.3 (76) | | 0.76 (0.44-1.33) |

*Odds ratio for previously undiagnosed OSA, calculated using a multivariable logistic model containing the same variables as Table 1. Bolded odds ratios are statistically significant.