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ASSOCIATION OF SLEEP-DISORDERED BREATHING WITH ERECTILE DYSFUNCTION IN COMMUNITY-DWELLING OLDER MEN

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Abstract

Purpose—To investigate the association between sleep-disordered breathing (SDB) and erectile dysfunction (ED) in older men.

Methods—We performed a cross-sectional analysis of community-dwelling men aged ≥ 67 years enrolled in the MrOS Sleep Study. Participants underwent overnight polysomnography (2003–2005) and completed sexual health questionnaires (2005–2006). We defined SDB using the apnea-hypopnea-index (AHI) or nocturnal hypoxemia. ED was defined using the Massachusetts Male Aging Study (MMAS) scale and, in sexually active men, the International Index of Erectile Function (IIEF-5). We used logistic regression to examine the association between SDB and ED.

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Results—Mean age was 76 ± 5 years. Of 2,676 men completing the MMAS, 70% had moderate-to-complete ED. Among 1,099 sexually active men completing the IIEF-5, 26% had moderate-to-severe ED. Higher AHI was associated with greater odds of MMAS-defined moderate-to-complete ED after adjusting for age and study site (OR=1.39; 95% CI: 1.00–1.92 for severe SDB vs none; p -trend=0.008), but not after further adjustment for BMI, socioeconomic status, and co-morbidities (OR=1.05; 95% CI: 0.75–1.49; p trend=0.452). Greater nocturnal hypoxemia was associated with increased odds of MMAS-defined moderate-to-complete ED (unadjusted OR=1.36; 95% CI: 1.04–1.80 vs none), but this was attenuated after adjustment for age and study site (OR=1.24; 95% CI: 0.92–1.66). SDB was not associated with ED by IIEF-5.

Conclusions—In this cross-sectional analysis in older men, SDB was associated with higher odds of ED in unadjusted analyses that was largely explained by higher BMI and increased comorbidity among men with SDB. Prospective studies accounting for obesity and multimorbidity would further clarify the association of SDB and ED.

Keywords

Erectile dysfunction; sleep-disordered breathing; sleep apnea

INTRODUCTION

Erectile dysfunction (ED) is a common sexual health problem among older men, affecting over 30 million men in the United States with more than 47% prevalence among men over 60 years of age^{1,2,3}. In addition to age, established risk factors for ED include hypertension (HTN), diabetes mellitus (DM) and other co-morbid conditions, smoking, low serum testosterone, and obesity^{2,4,5}. ED is associated with increased healthcare resource utilization and negatively impacts quality of life^{3,6}.

Sleep-disordered breathing (SDB), a disorder characterized by repeated cessation or reduction in airflow during sleep accompanied by hypoxemia, shares several common risk factors and co-morbid conditions with ED^{2,7}. In particular, older age, obesity, and smoking predispose to both SDB and ED^{2,7}. Indeed, patients with SDB may suffer disproportionately from ED when compared to the general population⁸. The high prevalence of ED among SDB patients may be due to this confluence of risk factors and co-morbidities rather than to SDB itself⁹. However, others suggest that SDB may independently lead to ED, through SDB-related hypoxia and sleep fragmentation that lead to occult pudendal nerve dysfunction and through psychogenic factors¹⁰. Should SDB lead to or exacerbate ED, then the corollary would be that treatment of SDB may represent a novel treatment for ED.

Published work to date regarding an independent association between SDB and ED is conflicting and limited to studies in middle-aged adults, with only a few studies utilizing the gold standard measure of SDB, polysomnography (PSG)^{9,11–13}. Therefore, we performed a cross-sectional analysis in older men to assess the independent association between SDB, as measured by PSG, and prevalent ED among community-dwelling older men participating in the Osteoporotic Fractures in Men (MrOS) Sleep Study.

METHODS

Participants

Between 2000–2002, 5,994 community-dwelling men aged 65 years and older were enrolled in the Osteoporotic Fractures in Men (MrOS) Study, the parent cohort for the Outcomes of Sleep Disorders in Older Men (MrOS Sleep) Study. Participants were recruited from six U.S. academic medical centers (Birmingham, AL; Minneapolis, MN; Palo Alto, CA; Pittsburgh, PA; Portland, OR; and San Diego, CA). Recruitment details have been published elsewhere^{14,15}. Two years later, of 5,994 enrollees, 3,135 men aged 67 and older were recruited for participation in the MrOS Sleep Study. Participants in the MrOS Sleep Study had overnight in-home polysomnography (PSG) at the sleep visit (2003–2005). They returned for a second study visit (Visit 2, 2005–2006) and completed sexual health questionnaires: the single-item Massachusetts Male Aging Study (MMAS) scale and, in the subset of men who reported being sexually active over the past six months, the 5-item International Index of Erectile Function questionnaire (IIEF-5). Of 3,135 MrOS Sleep Study enrollees, a total of 2,857 men had PSG and returned for Visit 2. Of those 2,857, 2,676 (93.7%) completed the MMAS questionnaire and 1,099 (38.5%) completed the IIEF-5 questionnaire. All men provided written informed consent, and the study was approved by the Institutional Review Board at each site.

Sleep Data Collection and Definition of Sleep Parameters

Participants underwent unattended, in-home, overnight sleep studies using a portable PSG device (Safiro model, Compumedics, inc.®). Trained and certified personnel performed home visits to set up the PSG device and returned the next morning to collect it. The downloaded sleep study data were transferred to the Central Sleep Reading Center (Cleveland, OH), where certified polysomnographic technologists scored the sleep study data. SDB was defined using the apnea-hypopnea index (AHI) and percent of sleep spent at $\text{SaO}_2 < 90\%$ (%time $\text{SaO}_2 < 90\%$). AHI was calculated by dividing the total number of apneas (defined as complete or near complete cessation of airflow for >10 seconds plus 4% oxygen desaturation) and hypopneas (defined by clear reduction of air in breathing amplitude that occurred for >10 seconds but did not meet the thresholds for apnea plus 4% oxygen desaturation) by the total time slept in hours (events/hour)¹⁶. Severity of SDB was defined according to AHI categories: normal (0–4.9 events/hour), mild (5–14.9 events/hour), moderate (15–29.9 events/hour), and severe (≥ 30 events/hour)¹⁶. SDB also was measured by nocturnal hypoxemia, using the %time $\text{SaO}_2 < 90\%$ in four categories: $<1\%$, 1–3.4%, 3.5–9.9%, and $\geq 10\%$ as in previous studies of nocturnal hypoxemia in the MrOS Sleep Study¹⁷.

Measures of Erectile Function

Data on sexual health were collected at the MrOS Study visit 2, on average 14 months after the sleep visit. ED was assessed using the self-reported single-item MMAS and, in the subset of men who self-reported sexual activity over the past six months, using the self-reported five-item International Index of Erectile Function questionnaire (IIEF-5) (Appendix). Based on the MMAS, ED was classified into four categories: completely, moderately, minimally, and not impotent⁴. Based on the IIEF-5 total score (range of scores, 5–25), ED was classified into five severity levels (severe 5–7, moderate 8–11, mild-moderate

12–16, mild 17–21, and no ED 22–25)¹⁸. For our analysis, ED outcomes were defined dichotomously according to clinically relevant levels of ED and previously published literature^{4,5,18}. For MMAS, minimal or no ED were grouped as no ED, and moderate or complete ED were grouped as ED. For IIEF-5, a cutoff score of 12 was used (severe and moderate ED vs. mild-moderate, mild, and no ED)¹⁸.

Other Variables

Information on race, marital status, highest level of education, socioeconomic status (SES) and total and bioavailable testosterone levels was collected at the baseline of the MrOS parent cohort study¹⁹. Participants' characteristics collected from the baseline MrOS Sleep visit included: age, body mass index (BMI), smoking status, alcohol use, sexual partners, self-reported health status, physical activity (Physical Activity Scale for Elderly), depression symptoms (Geriatric Depression Score), DM (self-reported DM or use of antidiabetic drugs), HTN (self-reported HTN or use of antihypertensive drugs), peripheral vascular disease, and heart disease (self-reported physician diagnosis for myocardial infarction, stroke, angina, congestive heart failure, or peripheral vascular disease), self-reported beta-blocker, selective serotonin re-uptake inhibitor (SSRI), and phosphodiesterase type 5 (PDE5) inhibitor use²⁰. Lower urinary tract symptoms (American Urological Association Symptom Index) were queried at visit 2 of MrOS Sleep²¹. Centrally trained personnel performed all study visits procedures, collected medical information, and verified self-reported current medications. A medication inventory was used to classify medications used within the preceding 30 days by matching each medication to its ingredient(s) based on the Iowa Drug Information Service (IDIS) Drug Vocabulary (College of Pharmacy, University of Iowa, Iowa City, IA)²².

Statistical Analysis

We compared baseline characteristics between this selected cohort and MrOS sleep participants who did not complete ED assessment using one-way analysis of variance (ANOVA) or chi-square tests for continuous and categorical variables, respectively. Similarly, we compared baseline characteristics across categories of MMAS-defined and IIEF-5-defined ED. We used logistic regression models to examine the unadjusted association between SDB in four categories and odds of ED. Thereafter, if the odds ratio remained statically significant, the models were further adjusted for age and study site. Finally, if the odds ratio was statistically significant after adjustment for age and study site, we used a backward elimination analysis to develop a fully adjusted logistic regression model. Candidate variables included in the backward elimination procedure were age and study site *a priori* plus other clinically relevant confounding variables that were statistically significantly associated with both predictor (SDB) and outcome (ED) ($p < 0.1$) in univariate models. For models presented, p for trend was reported. We additionally performed tests of interaction between SDB and key covariates *a priori* believed to be potential effect modifiers of the association between SDB and ED: BMI (continuous), and DM, HTN, and heart disease. If p for interaction was < 0.1 , we performed stratified analyses.

All statistical analyses were performed using Statistical Analysis Software (SAS) version 9.3 (SAS Institute Inc, Cary, North Carolina), and statistical significance was achieved at $\alpha=0.05$.

RESULTS

Participant Characteristics

The mean age of the 2,857 men who participated in the sleep study and returned for a second study visit was 76.3 ± 5.5 years, and most were Caucasian (90.7%) and married (84.4%). Compared to men who did not complete the MMAS sexual function questionnaire, men who completed it were younger, more likely to be married and college graduates, and they had better self-reported health and higher physical activity scores (Table 1). Additionally, sexually active men who completed the IIEF-5 versus those who did not had higher SES and testosterone levels, and were less likely to have co-morbidities or to use beta-blockers, SSRIs, or PDE5 inhibitors (Table 1).

Prevalence and Characteristics of Participants by Sleep-Disordered Breathing Category

By AHI, the prevalence of mild, moderate, and severe SDB was 34.3% ($n=980$), 16.5% ($n=471$), and 9.7% ($n=278$), respectively. Men with a higher AHI category were older, less likely to have college education, had lower SES and physical activity score, were more obese, were more likely to have co-morbid conditions, and had greater beta-blockers use (Table 2).

Twelve percent of men had 10 %time $\text{SaO}_2 < 90\%$. Men with higher %time $\text{SaO}_2 < 90\%$ were older, more likely to be white, less likely to have a college education, had lower physical activity scores and testosterone levels, and were more obese and more likely to have co-morbid conditions (Table 3).

Prevalence of Erectile Dysfunction

Of 2,676 men who completed the MMAS questionnaire, 27.2% had moderate ED and 42.6% had complete ED, measured by MMAS. Men with greater severity of SDB by AHI had higher prevalence of complete MMAS-defined ED (53% for severe vs 43%, 42% and 41% for moderate, mild and no SDB, respectively) (Table 2). Also, men with greater severity of nocturnal hypoxemia had higher prevalence of complete MMAS-defined ED (45% and 48% of men with %time $\text{SaO}_2 < 90\%$ 10 and 3.5–9.9%, respectively, versus 43% and 40% with %time $\text{SaO}_2 < 90\%$ 1–3.4% and $< 1\%$, respectively (Table 3).

Of 1,099 men who completed the IIEF-5 questionnaire, 9.7% had moderate ED and 16.0% had severe ED. Moderate to severe ED was most prevalent among those with severe SDB (by AHI) (32%) versus 23%, 26% and 25% for those with moderate, mild or no SDB, respectively (Table 2). However, we did not see a similar trend when SDB was defined as nocturnal hypoxemia (Table 3).

Association of Sleep-Disordered Breathing with Erectile Dysfunction

In the unadjusted regression model, greater severity of SDB (AHI) was strongly associated with greater odds of MMAS-defined moderate to complete ED (OR=1.57; 95%CI: 1.15–2.14 for severe SDB vs. none; p-trend<0.001) (Table 4). After adjusting for age and study site, this association persisted but was attenuated (OR=1.39; 95%CI: 1.00–1.92 for severe SDB vs. none; p-trend=0.008) (Table 4). However, after adjusting for age, study site, BMI, heart disease, DM, HTN, SES, and Geriatric Depression Score, the association between SDB (AHI) and MMAS-defined moderate to complete ED was attenuated further and no longer statistically significant (OR=1.05; 95%CI: 0.75–1.49 for severe SDB vs. none; p-trend=0.452) (Table 4). There were no significant interactions with AHI to predict MMAS-defined ED. In the unadjusted regression model, greater severity of AHI was associated with greater odds of IIEF-5-defined moderate to severe ED, but this association was not statistically significant (OR=1.37; 95%CI: 0.81–2.29 for severe SDB vs. none; p-trend=0.694, unadjusted).

Greater severity of SDB as defined by %time SaO₂<90% was associated with increased odds of MMAS-defined moderate to complete ED (OR=1.36; 95%CI: 1.04–1.80 for %time SaO₂<90% 10% vs. <1%; p-trend=0.005, unadjusted). However, this association was attenuated after adjusting for age and study site, and of borderline statistical significance (OR=1.24; 95%CI: 0.92–1.66 for %time SaO₂<90% 10% vs. <1%; p-trend=0.053). Greater severity of nocturnal hypoxemia was not associated with higher odds of IIEF-5-defined moderate to severe ED (OR=0.78; 95%CI: 0.49–1.25 for %time SaO₂<90% 10% vs. <1%; p-trend=0.535, unadjusted).

DISCUSSION

In this cohort of community-dwelling older men, greater severity of SDB, as measured by either AHI or %time SaO₂<90%, was associated with greater odds of moderate to complete ED in unadjusted models. However, these associations were largely explained by older age, higher BMI, presence of heart disease, DM, HTN, depression symptoms, and lower SES among men with SDB, and were not observed in the subset of men with recent sexual activity who completed the IIEF-5 questionnaire. Our findings suggest that although SDB and ED frequently occur together, this observed association may be explained by older age, higher BMI and more frequent co-morbid conditions in older men with SDB.

Previous studies that have examined the association between PSG-defined SDB and ED have reported conflicting results. A cross-sectional study of 209 men reported that severe, but not mild, SDB was associated with ED¹¹. Another cross-sectional analysis of 401 men undergoing PSG for suspected SDB found a significant association between SDB (AHI ≥ 5) and mild to severe ED as defined by IIEF-15²³, but only mean nocturnal SaO₂ was independently associated with ED after multivariate adjustment²³.

Notably, a few studies reported that treatment of SDB with continuous positive airway pressure (CPAP) improves ED in some patients^{12,24}. For example, in an uncontrolled study in men without DM or other metabolic disorders but with SDB and ED, defined by an inability to obtain or maintain an erection sufficient for sexual intercourse (≥ 6 months),

Gonclaves et al. reported that 13 out of 17 men (75%) who were treated with nasal CPAP for one month showed complete disappearance of their ED¹². Another uncontrolled study conducted in 60 men with SDB reported that 12 men (20%) showed improved IIEF-5 score (from 10±6 to 19±6; p<0.01) after 17 months of CPAP treatment²⁴. Aging men with co-morbidities such as DM, HTN, and vascular diseases were excluded in this study²⁴.

SDB produces several neural, hormonal, and vascular abnormalities that may lead to ED. It has been suggested that occult nerve dysfunction, specifically pudendal neuropathy, due to SDB-related hypoxia may be an underlying cause of ED in men with SDB¹⁰. Sleep fragmentation and nocturnal hypoxia from SDB may lead to impaired function of the hypothalamic-gonadal axis and subsequent reduction in androgen production²⁵. Indeed, in our study we found that levels of total and bioavailable testosterone were significantly lower in men with greater severity of nocturnal hypoxemia. Other suggested mechanisms include sympathetic activation and vasoconstriction leading to decreased arterial penile flow, oxidative stress and endothelial impairment, glucose intolerance and insulin resistance, and physiological factors due to daytime sleepiness and SDB-related mood changes^{26–29}. Finally, SDB causes HTN which is a well-established risk factor for development of ED^{2,30}.

Our study has several strengths. The MrOS Sleep Study is a large, multi-center, well-characterized cohort of community-dwelling older men in the U.S. Our study is the first to examine the association between SDB and ED in an older cohort. Additional strengths of our study include diagnosis of SDB using polysomnography, measurement of SDB by both AHI and nocturnal hypoxemia, ascertainment of ED by two extensively validated instruments, and adjustment for potential confounders and effect modifiers of the association between SDB and ED.

Our study also has some limitations. First, because the sexual health questionnaires were administered more than a year after the sleep study, we do not know the status of ED at the time of sleep study. Therefore, we cannot comment on a temporal association between SDB and ED. Also, given our cross-sectional design, there is potential for over-adjustment for factors such as heart disease and HTN that may be on the causal pathway; this may bias our results toward the null hypothesis. Finally, the generalizability of our findings is limited to community-dwelling, mostly Caucasian, older men.

CONCLUSIONS

Our findings suggest that SDB and ED frequently occur together but this observed association may be explained by older age, higher BMI and more frequent co-morbid conditions in older men with SDB.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations and Acronyms

AHI	apnea-hypopnea-index
BMI	body mass index
CI	confidence interval
CPAP	continuous positive airway pressure
DM	diabetes mellitus
ED	erectile dysfunction
HTN	hypertension
IIEF-5	5-item International Index of Erectile Function
MMAS	Massachusetts Male Aging Study
OR	odds ratio
PSG	polysomnography
RDI	respiratory disturbance index
SDB	sleep-disordered breathing
SES	socioeconomic status
%time SaO₂<90%	percent of sleep spent at SaO ₂ <90%

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APPENDIX. Sexual Function Questionnaires

International Index of Erectile Function-5 Questionnaire					
How do you rate your confidence that you could get and keep an erection?	Very low 1	Low 2	Moderate 3	High 4	Very high 5
When you had erections with sexual stimulation, how often were your erections hard enough for penetration?	Almost never or never 1	A few times (much less than half the time) 2	Sometimes (about half the time) 3	Most times (much more than half the time) 4	Almost always or always 5
During sexual intercourse, how often were you able to maintain your erection after you had penetrated (entered) your partner?	Almost never or never 1	A few times (much less than half the time) 2	Sometimes (about half the time) 3	Most times (much more than half the time) 4	Almost always or always 5
During sexual intercourse, how difficult was it to maintain your erection to completion of intercourse?	Extremely difficult 1	Very difficult 2	Difficult 3	Slightly difficult 4	Not difficult 5

International Index of Erectile Function-5 Questionnaire

When you attempted sexual intercourse, how often was it satisfactory for you?	Almost never or never 1	A few times (much less than half the time) 2	Sometimes (about half the time) 3	Most times (much more than half the time) 4	Almost always or always 5
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Massachusetts Male Aging Study Single-item Questionnaire

Erectile dysfunction (sometimes called impotence) means not being able to get and keep an erection that is rigid enough for satisfactory sexual activity. How would you describe yourself?	1. Not impotent—always able to get and keep an erection good enough for sexual intercourse	2. Minimally impotent—usually able to get and keep an erection good enough for sexual intercourse	3. Moderately impotent—sometimes able to get and keep an erection good enough for sexual intercourse	4. Completely impotent—never able to get and keep an erection good enough for sexual intercourse
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	All Participants (N= 2,857)	MMAS Questionnaire			IIIEF-5 Questionnaire		
		Completers (N= 2,676)	Noncompleters (N= 181)	p value	Completers (N= 1,099)	Noncompleters (N= 1,758)	p value
Hypertension	1780 (62.3)	1656 (61.9)	124 (68.9)	0.06	651 (59.2)	1129 (64.3)	0.007
PVD	282 (10.0)	259 (9.8)	23 (13.5)	0.1247	85 (7.8)	197 (11.4)	0.002
Lower urinary tract symptoms, n(%)							
(1–7) mild	1414 (49.9)	1331 (49.9)	83 (49.4)	0.2419	576 (52.4)	838 (48.3)	0.006
(8–19) moderate	1196 (42.2)	1119 (42.0)	77 (45.8)		456 (41.5)	740 (42.6)	
(20–35) severe	225 (7.9)	217 (8.1)	8 (4.8)		67 (6.1)	158 (9.1)	
Medications							
Beta-blockers, n(%)	792 (27.7)	740 (27.7)	52 (28.7)	0.7543	271 (24.7)	521 (29.6)	0.004
SSRI, n(%)	124 (4.3)	112 (4.2)	12 (6.6)	0.1183	37 (3.4)	87 (5.0)	0.043
PDE5 inhibitors, n(%)	62 (2.2)	61 (2.3)	1 (0.6)	0.1228	51 (4.6)	11 (0.6)	<001
Total testosterone (ng/ml), mean (SD)	412.1 ± 165.9	411.0 ± 167.5	427.1 ± 142.5	0.4571	441.3 ± 165.2	394.1 ± 164.0	<001
Bioavailable testosterone (ng/dl), mean (SD)	211.7 ± 70.5	211.5 ± 70.6	213.3 ± 68.6	0.8483	227.6 ± 69.7	202.0 ± 69.2	<001
AHI, n(%)							
Normal (0–4.9)	1128 (39.5)	1054 (39.4)	74 (40.9)	0.5354	458 (41.7)	670 (38.1)	0.003
Mild (5–14.9)	980 (34.3)	926 (34.6)	54 (29.8)		380 (34.6)	600 (34.1)	
Moderate (15–29.9)	471 (16.5)	436 (16.3)	35 (19.3)		182 (16.6)	289 (16.4)	
Severe (≥ 30)	278 (9.7)	260 (9.7)	18 (9.9)		79 (7.2)	199 (11.3)	
Nocturnal Hypoxemia (%time SaO2<90%), n(%)							
<1%	1393 (48.8)	1303 (48.6)	90 (49.7)	0.1708	570 (51.9)	823 (46.8)	0.036
1–3.4%	751 (26.3)	714 (26.7)	37 (20.5)		283 (25.7)	468 (26.6)	
3.5%–9.9%	364 (12.7)	339 (12.7)	25 (13.8)		124 (11.3)	240 (13.7)	
10%	349 (12.2)	320 (12.0)	29 (16.0)		122 (11.1)	227 (12.9)	

ED: erectile dysfunction; IIIEF-5: five-item International Index of Erectile Function; MMAS: single-item Massachusetts Male Aging Study; PVD: peripheral vascular disease; BMI: body-mass-index; SES: socioeconomic status; PDE5 inhibitors: phosphodiesterase type 5 inhibitors; AHI: apnea-hypopnea index; SSRI: selective serotonin reuptake inhibitors

p value is calculated across categories of ED using one-way analysis of variance (ANOVA) or chi-square tests for continuous and categorical variables respectively

Table 2

Demographics and Clinical Characteristics of Participants By Categories of AHI

	Apnea-Hypopnea-Index (AHI)				p value
	Normal (0–4.9) (N= 1,128)	Mild (5–14.9) (N= 980)	Moderate (15–29.9) (N= 471)	Severe (≥ 30) (N= 278)	
Age (years), mean (SD)	76.2 ± 5.5	76.11 ± 5.5	76.4 ± 5.3	77.5 ± 5.4	0.003
Race					
Caucasian, n(%)	1025 (90.9)	899 (91.7)	414 (87.9)	253 (91.0)	0.128
BMI (kg/m ²), n(%)					
Low normal (21.9)	97 (8.6)	31 (3.2)	15 (3.2)	5 (1.8)	<.001
Normal (22.0–24.9)	341 (30.2)	219 (22.3)	81 (17.3)	39 (14.0)	
Overweight (25–29.9)	543 (48.2)	518 (52.9)	241 (51.4)	123 (44.3)	
Obese (≥ 30)	147 (13.0)	212 (21.6)	132 (28.1)	111 (39.9)	
Marital Status					
Married, n(%)	951 (84.3)	832 (84.9)	405 (86.0)	223 (80.2)	0.188
At least one current sexual partner, n(%)	736 (79.8)	597 (75.1)	287 (76.3)	153 (71.2)	0.019
Currently smoking, n(%)	31 (2.8)	16 (1.6)	6 (1.3)	4 (1.4)	0.132
Alcohol Use					
3 drinks per week, n(%)	468 (61.9)	389 (62.5)	193 (62.1)	102 (57.3)	0.643
College Education, n(%)	706 (62.6)	538 (54.9)	234 (49.7)	130 (46.8)	<.001
Excellent/Very good Health status, n(%)	997 (88.5)	850 (86.8)	403 (85.6)	229 (82.4)	0.043
Physical Activity					
PASE score, mean (SD)	146.1 ± 71.8	151.1 ± 70.3	140.1 ± 69.7	139.2 ± 74.4	0.002
SES Ladder in USA, mean (SD)	7.3 ± 1.6	7.4 ± 1.6	7.2 ± 1.7	7.1 ± 1.6	0.055
SES Ladder in community, mean (SD)	7.1 ± 1.7	7.0 ± 1.7	6.9 ± 1.6	6.7 ± 1.8	0.001
Medical history, n(%)					
Heart Disease	359 (31.8)	329 (33.6)	172 (36.5)	115 (41.4)	0.015
Diabetes Mellitus	117 (10.4)	136 (13.9)	77 (16.4)	49 (17.6)	<.001
Hypertension	648 (57.5)	601 (61.4)	321 (68.2)	210 (75.5)	<.001
PVD	83 (7.5)	103 (10.7)	51 (11.0)	45 (16.6)	<.001
Depression symptoms, n(%)					
(0–4) normal,	1023 (90.8)	907 (92.7)	414 (87.9)	251 (90.6)	0.043

	Apnea-Hypopnea-Index (AHI)					p value
	Normal (0–4.9) (N= 1,128)	Mild (5–14.9) (N= 980)	Moderate (15–29.9) (N= 471)	Severe (≥ 30) (N= 278)		
(5–10) mildly depressed	96 (8.5)	66 (6.7)	48 (10.2)	22 (7.9)		
(11–15) severely depressed	8 (0.7)	6 (0.6)	9 (1.9)	4 (1.5)		
Lower urinary tract symptoms, n(%)						
(1–7) mild	575 (51.4)	472 (48.5)	236 (50.3)	131 (48)		0.185
(8–19) moderate	447 (39.9)	439 (45.0)	194 (41.4)	116 (42.5)		
(20–35) severe	97 (8.7)	63 (6.5)	39 (8.3)	26 (9.5)		
Medications						
Beta-blockers, n(%)	283 (25.1)	272 (27.8)	130 (27.6)	107 (38.5)		<.001
SSRI, n(%)	44 (3.9)	40 (4.1)	29 (6.2)	11 (4.0)		0.210
PDE5 inhibitors, n(%)	26 (2.3)	17 (1.7)	12 (2.6)	7 (2.5)		0.695
Total testosterone (ng/ml), mean (SD)	427.3 ± 178.5	412.1 ± 167.4	393.5 ± 139.6	384.4 ± 148.7		0.090
Bioavailable testosterone (ng/dl), mean (SD)	215.4 ± 69.4	214.0 ± 77.9	205.2 ± 60.5	200.1 ± 63.6		0.285
ED measured by IIEF-5, n(%)						
no ED (22–25)	133 (29.0)	109 (28.7)	60 (33.0)	18 (22.8)		0.659
Mild ED(17–21)	145 (31.7)	109 (28.7)	50 (27.5)	21 (26.6)		
Mild-Moderate ED (12–16)	64 (14.0)	62 (16.3)	31 (17.0)	15 (19.0)		
Moderate ED (8–11)	44 (9.6)	33 (8.7)	17 (9.3)	12 (15.2)		
Severe ED (1–7)	72 (15.7)	67 (17.6)	24 (13.2)	13 (16.4)		
ED measured by MMAS, n(%)						
Not impotent	172 (16.3)	150 (16.2)	63 (14.4)	26 (10.0)		0.007
Minimal	175 (16.6)	132 (14.2)	52 (11.9)	36 (13.8)		
Moderate	278 (26.4)	259 (28.0)	132 (30.3)	60 (23.1)		
Complete	429 (40.7)	385 (41.6)	189 (43.4)	138 (53.1)		

ED: erectile dysfunction; IIEF-5: five-item International Index of Erectile Function; PVD: peripheral vascular disease; BMI: body-mass-index; SES: socioeconomic status; PDE5 inhibitors: phosphodiesterase type 5 inhibitors; RDI: respiratory disturbance index; SSRI: selective serotonin reuptake inhibitors

p value is calculated across categories of ED using one-way analysis of variance (ANOVA) or chi-squared tests for continuous and categorical variables respectively

Table 3
Demographics and Clinical Characteristics of Participants By Categories of Nocturnal Hypoxemia

	Nocturnal Hypoxemia (%time SaO ₂ <90%)				p value
	<1% (N= 1,393)	1–3.4% (N= 751)	3.5%–9.9% (N= 364)	10% (N= 349)	
Age (years), mean (SD)	76.1 ± 5.5	76.4 ± 5.4	76.6 ± 5.6	76.9 ± 5.2	0.059
Race					
Caucasian, n(%)	1244 (89.3)	684 (91.1)	340 (93.4)	323 (92.6)	0.048
BMI (kg/m ²), n(%)					
Low normal (21.9)	108 (7.8)	25 (3.3)	11 (3.0)	4 (1.1)	<.001
Normal (22.0–24.9)	449 (32.2)	154 (20.6)	45 (12.4)	32 (9.2)	
Overweight (25–29.9)	672 (48.2)	402 (53.7)	194 (53.3)	157 (45.0)	
Obese (30)	164 (11.8)	168 (22.4)	114 (31.3)	156 (44.7)	
Marital Status					
Married, n(%)	1190 (85.4)	634 (84.4)	305 (83.8)	282 (80.8)	0.200
At least one current sexual partner, n(%)	901 (79.2)	463 (76.5)	211 (72.8)	198 (71.7)	0.015
Currently smoking, n(%)	27 (1.9)	14 (1.9)	4 (1.1)	12 (3.4)	0.152
Alcohol Use					
3 drinks per week, n(%)	588 (62.2)	312 (64.2)	138 (58.7)	114 (57.0)	0.249
College Education, n(%)	862 (61.9)	402 (53.5)	187 (51.4)	157 (45.0)	<.001
Excellent/Very good Health status, n(%)	1224 (87.9)	668 (89.0)	306 (84.3)	281 (80.5)	<.001
Physical Activity					
PASE score, mean (SD)	148.7 ± 71.0	148.5 ± 71.6	141.0 ± 72.6	135.9 ± 69.5	0.002
SES Ladder in USA, mean (SD)	7.3 ± 1.6	7.3 ± 1.7	7.4 ± 1.7	7.1 ± 1.6	0.112
SES Ladder in community, mean (SD)	7.1 ± 1.6	6.9 ± 1.7	6.9 ± 1.7	6.6 ± 1.7	<.001
Medical history, n(%)					
Heart Disease	444 (31.9)	271 (36.1)	126 (34.7)	134 (38.4)	0.063
Diabetes Mellitus	151 (10.8)	119 (15.9)	49 (13.5)	60 (17.2)	0.001
Hypertension	810 (58.2)	476 (63.4)	248 (68.3)	246 (70.5)	<.001
PVD	104 (7.6)	74 (9.9)	50 (14.0)	54 (15.9)	<.001
Depression symptoms, n(%)					
(0–4) normal,	1269 (91.2)	695 (92.5)	322 (88.7)	309 (88.8)	0.227

	Nocturnal Hypoxemia (%time SaO ₂ <90%)					p value
	<1% (N= 1,393)	1–3.4% (N= 751)	3.5%–9.9% (N= 364)	10% (N= 349)		
(5–10) mildly depressed	113 (8.1)	48 (6.4)	36 (9.9)	35 (10.1)		
(11–15) severely depressed	10 (0.7)	8 (1.1)	5 (1.4)	4 (1.1)		
Lower urinary tract symptoms, n(%)						
(1–7) mild	697 (50.4)	387 (51.7)	170 (47.1)	160 (46.6)		0.547
(8–19) moderate	575 (41.6)	307 (41.0)	157 (43.5)	157 (45.8)		
(20–35) severe	111 (8.0)	54 (7.2)	34 (9.4)	26 (7.6)		
Medications						
Beta-blockers, n(%)	363 (26.1)	207 (27.6)	107 (29.4)	115 (33.0)		0.066
SSRI, n(%)	59 (4.2)	28 (3.7)	23 (6.3)	14 (4.0)		0.237
PDE5 inhibitors, n(%)	27 (1.9)	23 (3.1)	5 (1.4)	7 (2.0)		0.231
Total testosterone (ng/ml), mean (SD)	430.9 ± 175.0	411.0 ± 164.1	377.7 ± 136.9	370.6 ± 145.6		<.001
Bioavailable testosterone (ng/dl), mean (SD)	219.9 ± 73.0	210.8 ± 74.8	197.3 ± 55.9	192.8 ± 57.0		0.001
ED measured by IIEF-5, n(%)						
no ED (22–25)	165 (28.9)	79 (27.9)	34 (27.4)	42 (34.4)		0.962
Mild ED(17–21)	172 (30.2)	87 (30.7)	33 (26.6)	33 (27.1)		
Mild-Moderate ED (12–16)	86 (15.1)	42 (14.8)	23 (18.6)	21 (17.2)		
Moderate ED (8–11)	54 (9.5)	29 (10.3)	12 (9.7)	11 (9.0)		
Severe ED (1–7)	93 (16.3)	46 (16.3)	22 (17.7)	15 (12.3)		
ED measured by MMAS, n(%)						
Not impotent	215 (16.5)	113 (15.8)	48 (14.2)	35 (10.9)		0.136
Minimal	206 (15.8)	101 (14.1)	40 (11.8)	48 (15.0)		
Moderate	355 (27.2)	194 (27.2)	88 (25.9)	92 (28.8)		
Complete	527 (40.5)	306 (42.9)	163 (48.1)	145 (45.3)		

ED: erectile dysfunction; IIEF-5: five-item International Index of Erectile Function; PVD: peripheral vascular disease; BMI: body-mass-index; SES: socioeconomic status; PDE5 inhibitors: phosphodiesterase type 5 inhibitors; RDI: respiratory disturbance index; SSRI: selective serotonin reuptake inhibitors

p value is calculated across categories of ED using one-way analysis of variance (ANOVA) or chi-squared tests for continuous and categorical variables respectively

Table 4

The association between Apnea-Hypopnea-Index (AHI) and moderate to complete ED measured by MMAS

Models	Odds Ratio(95%CI) by Category of AHI				
	Normal (n=1,054)	Mild (n=926)	Moderate (n=436)	Severe (n=260)	p for trend
Unadjusted	1.0(referent)	1.12(0.93–1.36)	1.37(1.07–1.76)	1.57(1.15–2.14)	<.001
Adjusted for age and study site	1.0(referent)	1.14(0.93–1.39)	1.36(1.05–1.76)	1.39(1.00–1.92)	0.008
Full model [/]	1.0(referent)	1.09(0.89–1.34)	1.14(0.87–1.5)	1.05(0.75–1.49)	0.452

[/] Adjusted for age, study site, and all covariates that are significantly associated at p<0.1 with both the predictor and outcome. These covariates are body-mass index (BMI), socioeconomic status, heart disease, diabetes mellitus, hypertension, and geriatric depression score.