Racial/Ethnic Differences in Sleep Disturbances: The Multi-Ethnic Study of Atherosclerosis (MESA)

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Objectives: There is limited research on racial/ethnic variation in sleep disturbances. This study aimed to quantify the distributions of objectively measured sleep disordered breathing (SDB), short sleep duration, poor sleep quality, and self-reported sleep disturbances (e.g., insomnia) across racial/ethnic groups.

Design: Cross-sectional study.

Setting: Six US communities.

Participants: Racially/ethnically diverse men and women aged 54–93 y in the Multi-Ethnic Study of Atherosclerosis Sleep Cohort (n = 2,230).

Interventions: N/A.

Measurements and Results: Information from polysomnography-measured SDB, actigraphy-measured sleep duration and quality, and self-reported daytime sleepiness were obtained between 2010 and 2013. Overall, 15.0% of individuals had severe SDB (apnea-hypopnea index [AHI] ≥ 30); 30.9% short sleep duration (< 6 h); 6.5% poor sleep quality (sleep efficiency < 85%); and 13.9% had daytime sleepiness. Compared with Whites, Blacks had higher odds of sleep apnea syndrome (AHI ≥ 5 plus sleepiness) (sex-, age-, and study site-adjusted odds ratio [OR] = 1.78, 95% confidence interval [CI]: 1.20, 2.63), short sleep (OR = 4.95, 95% CI: 3.56, 6.90), poor sleep quality (OR = 1.57, 95% CI: 1.00, 2.48), and daytime sleepiness (OR = 1.89, 95% CI: 1.38, 2.60). Hispanics and Chinese had higher odds of SDB and short sleep than Whites. Among non-obese individuals, Chinese had the highest odds of SDB compared to Whites. Only 7.4% to 16.2% of individuals with an AHI ≥ 15 reported a prior diagnosis of sleep apnea.

Conclusions: Sleep disturbances are prevalent among middle-aged and older adults, and vary by race/ethnicity, sex, and obesity status. The high prevalence of sleep disturbances and undiagnosed sleep apnea among racial/ethnic minorities may contribute to health disparities.

Keywords: apnea-hypopnea index, body mass index, daytime sleepiness, obesity, polysomnography, race/ethnicity, sleep disordered breathing, sleep disturbance, sleep duration, sleep quality

Citation: Chen X, Wang R, Zee P, Lutsey PL, Javaheri S, Alcántara C, Jackson CL, Williams MA, Redline S. Racial/ethnic differences in sleep disturbances: the Multi-Ethnic Study of Atherosclerosis (MESA). *SLEEP* 2015;38(6):877–888.

INTRODUCTION

The prevalence of sleep disordered breathing (SDB), short sleep duration, and insomnia has increased substantially over the past two decades.[1,2] Epidemiologic studies have linked sleep disturbances to adverse health outcomes including obesity,[3] hypertension,[3] cardiovascular disease (CVD),[3,4] premature mortality,[5,6] impaired quality of life,[7] and economic burden.[8] An understanding of the distributions of sleep disturbances across sociodemographic groups may inform public health efforts aimed at reducing health and economic burdens of sleep disturbances.[9]

Previous research has indicated that SDB and other sleep disturbances are common among men and older individuals, and may vary across racial/ethnic groups.[2,9–14] Few population-based studies, however, have quantified differences in sleep disturbances across multiple racial/ethnic groups, and even fewer have included Asian Americans.[13] Prior epidemiologic studies have often relied on self-reported sleep information,[9,10,12,15] which have limitations in accuracy.[16] Polysomnography (PSG) is the gold-standard method for the assessment of SDB.[17] Wrist actigraphy is a valid and reliable method for assessing sleep duration and quality in individuals' home environment.[16,18] Few population-based studies have objectively measured sleep disturbances with both PSG and actigraphy, and those that have, had limited racial/ethnic diversity.[14,19,20]

This study sought to quantify the distributions of objectively measured SDB, short sleep duration, poor sleep quality, and self-reported sleep disturbances (e.g., insomnia) across racial/ethnic groups represented in the Multi-Ethnic Study of Atherosclerosis (MESA). Because obesity is frequently co-morbid with sleep disturbances,[14,21] we also examined the extent to which racial/ethnic differences in sleep disturbances were explained by differences in body mass index (BMI).

METHODS

Study Design and Sample

The study design for MESA has been published.[22] Briefly, MESA is a multisite prospective study designed to investigate

the prevalence and progression of subclinical CVD and to identify risk factors for incident CVD in a racially/ethnically diverse sample. Between July 2000 and August 2002, a total of 6,814 men and women who identified themselves as White, Black/African American, Hispanic, or Chinese aged 45–84 y and free of clinically apparent CVD were recruited from six US communities: Baltimore City and Baltimore County, MD; Chicago, IL; Forsyth County, NC; Los Angeles County, CA; Northern Manhattan and the Bronx, NY; and St. Paul, MN.

At MESA Exam 5 (2010–2013), 10 y after the initial examination, all MESA participants other than those reporting regular use of oral devices, nocturnal oxygen, or nightly positive airway pressure (PAP) devices were invited to participate in the MESA Sleep Ancillary Study, which consisted of PSG, actigraphy, and sleep questionnaire data collected during an in-home examination. Of 4,077 participants approached, 147 (6.5%) were ineligible (95 due to a history of the PAP use (2%); 4 due to use of an oral appliance; and 4 due to oxygen use) and 141 participants lived too far away to participate. Of the remaining 3,789 participants, 2,261 participated in the sleep exam (59.7%). Comparison of characteristics between sleep study participants and those who did not participate in the sleep examination showed that nonparticipants were slightly more likely to be White, older, current/ex-smokers, and to have hypertension and chronic obstructive pulmonary disease. However, there was no statistically significant difference in the prevalence of self-report doctor-diagnosed sleep apnea (Table S1, supplemental material). In total, 2,060 participants had successful PSG data, 2,156 had actigraphy data, and 2,240 participants completed sleep questionnaires.

Institutional Review Board approval was obtained at each study site and written informed consent was obtained from all participants.

Measures

PSG-Measured SDB

PSG was conducted using a 15-channel monitor (Compumedics Somte System; Compumedics Ltd., Abbotsville, Australia). The recording montage included electroencephalography (EEG), bilateral electrooculograms, a chin electromyography (EMG), bipolar electrocardiography (ECG), thoracic and abdominal respiratory inductance plethysmography, airflow measured by thermocouple and nasal pressure cannula, finger pulse oximetry, and bilateral limb movements. PSG provided quantitative assessments of levels of overnight hypoxemia, apneas and hypopneas, and sleep stage distributions. Sleep stages and EEG (cortical) arousals were scored according to published guidelines[23] adapted from the Sleep Heart Health Study.[24,25]

Apneas were scored when the thermocouple signal flattened or nearly flattened for greater than 10 sec. Hypopneas were scored when the amplitude of the sum of the abdominal and thoracic inductance signals or the nasal pressure flow signal decreased by 30% or more for greater than or equal to 10 sec. Events were classified as either "central" or "obstructive" according to the presence of absence of respiratory effort. Specialized software link apnea and hypopnea with data from the oxygen saturation and EEG signals, allowing each event to be characterized according to the degree of associated desaturation and arousal. Apnea-hypopnea index (AHI) was calculated based on the average number of all apneas plus hypopneas associated with a 4% desaturation per hour of sleep. SDB was defined as an AHI ≥ 5 events/h, and further categorized as: mild (AHI = 5–14), moderate (AHI = 15–29), and severe (AHI ≥ 30).

Actigraphy-Measured Sleep Duration and Quality

Actigraphy was performed using the Actiwatch Spectrum wrist actigraph (Philips Respironics, Murrysville, PA) worn on participants' nondominant wrists for 7 consecutive days, while participants completed a sleep diary over the same period.[26] Actigraphic data during 30-sec epochs were scored as sleep or wake by Actiware-Sleep version 5.59 analysis software (Mini-Mitter Co, Inc, Bend, OR). A validated algorithm was used in which activity counts recorded during the measured epoch were modified by the level of activity in the surrounding 2-min time period (e.g., ± 2 min) to yield the final activity count for each epoch.[27] Sleep duration and sleep quality (sleep maintenance efficiency) were estimated for each day. Short sleep duration was defined as an average of sleep duration < 6 h and 6–7 h. Long sleep duration was defined as ≥ 8 h, which represented approximately the highest 12% of the study sample. The choice of sleep duration (7–8 h) as the reference was based on the literature.[6,12] Poor sleep quality was defined as having sleep maintenance efficiency (percentage of sleep time after sleep onset/sleep period) < 85%.[28]

Sleep Questionnaires

Information pertaining to doctor-diagnosed sleep apnea, habitual snoring, insomnia, and excessive daytime sleepiness was collected using validated instruments.[29–31]

Doctor-Diagnosed Sleep Apnea: Information on doctor-diagnosed sleep apnea was obtained from the sleep questionnaire survey: "Have you ever been told by a doctor that you had sleep apnea (a condition in which breathing stops briefly during sleep)?" Those who answered 'yes' were defined as having doctor-diagnosed sleep apnea.

Habitual Snoring: Participants were asked: (a) "Have you ever snored?" and, if yes, (b) "How often do you snore?" Habitual snoring was considered if participants who reported snoring sometimes (3–5 nights/w) or always/almost always (6–7 nights/w).

Insomnia: A validated five-item Women's Health Initiative Insomnia Rating Scale (WHIIRS) was used to measure insomnia.[30] The WHIIRS assesses insomnia symptoms including long sleep latency, sleep maintenance insomnia, early morning awakening, and poor sleep quality over the past 4 w. The score ranges from 0 to 4 for each item (0 to 20 total score range). Insomnia was defined as a WHIIRS score > 10.

Excessive Daytime Sleepiness: The Epworth Sleepiness Scale (ESS)[31] was applied to define excessive daytime sleepiness using eight scenarios scored on a four-point Likert scale from 0 to 3. The total score of the ESS ranged from 0 to 24. Those with an ESS score > 10 were defined as having excessive daytime sleepiness.

Sleep apnea syndrome (SAS) was defined as having an AHI ≥ 5 plus an ESS score > 10.[2]

Table 1—Sociodemographic characteristics of study participants across racial/ethnic groups.

	White		Black		Hispanic		Chinese		
	n	% or mean (SD)	n	% or mean (SD)	n	% or mean (SD)	n	% or mean (SD)	P value[a]
Total	828	37.1	612	27.4	528	23.7	262	11.7	
Sex, %									
Men	382	46.1	272	44.4	248	47	130	49.6	0.550
Women	446	53.9	340	55.6	280	53	132	50.4	
Age (years), mean (SD)	828	68.8 (9.3)	612	68.8 (9.1)	528	68.6 (9.4)	262	67.7 (8.9)	0.379
Age group, %									
54–64 years	321	38.8	236	38.6	207	39.2	113	43.1	0.865
65–74 years	257	31.0	198	32.4	171	32.4	79	30.2	
75–93 years	250	30.2	178	29.1	150	28.4	70	26.7	
Study site, %									
Baltimore, MD	157	19.0	173	28.3	0	0.0	0	0.0	< 0.001
Chicago, IL	174	21.0	99	16.2	0	0.0	119	45.4	
Forsyth, NC	153	18.5	185	30.2	1	0.2	0	0.0	
Los Angeles, CA	40	4.8	44	7.2	159	30.1	143	54.6	
New York, NY	76	9.2	111	18.1	197	37.3	0	0.0	
St. Paul, MN	228	27.5	0	0.0	171	32.4	0	0.0	
BMI (kg/m^2), mean (SD)	828	28.1 (5.4)	612	30.3 (5.6)	528	30.1 (5.5)	262	24.2 (3.3)	< 0.001
BMI category[b], %									
BMI < 25 kg/m^2	258	31.2	99	16.2	84	15.9	168	64.1	< 0.001
BMI = 25–29 kg/m^2	323	39.0	215	35.1	211	40.0	82	31.3	
BMI ≥ 30 kg/m^2	247	29.8	298	48.7	233	44.1	12	4.6	

[a]Analysis of variance was conducted for continuous variables and Chi-square test was conducted for categorical variables. [b]By using the Asian criteria, the prevalence of overweight (BMI = 23–24 kg/m^2) and obesity (BMI ≥ 25 kg/m^2) among Chinese was 27.1% and 35.9%, respectively. BMI, body mass index; SD, standard deviation.

Covariates

Participants were grouped into three age categories: 54–64 y, 65–74 y, and 75–93 y. Race/ethnicity was self-identified and categorized as: non-Hispanic White, non-Hispanic Black/African American, Hispanic, and Chinese. Measured weight and height were used to calculate BMI, and categorized as follows: < 25, 25–29.9, and ≥ 30 kg/m^2, to represent normal, overweight, and obese individuals for all analyses.[32] We also defined normal, overweight, and obese categories for Chinese participants as follows: < 23, 23–24, and ≥ 25 kg/m^2 based on the International Association for the Study of Obesity and the International Obesity Task Force guidelines for Asians.[33]

Statistical Analysis

Frequency distributions of sociodemographic characteristics and sleep disturbances were determined by performing cross-tabulations across racial/ethnic groups. Analysis of variance was used to evaluate unadjusted mean differences for continuous variables. Age-adjusted means of AHI and sleep duration were estimated from general linear models. Chi-square tests were used to evaluate the differences in the distributions of categorical variables. Univariate and multivariable logistic regression procedures were used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) of sleep disturbances according to racial/ethnic groups. Sex, age, study site, and BMI were included in final models.

Multinomial logistic regression analyses were conducted for SDB (reference: normal (AHI < 5); mild, moderate, and severe SDB) and sleep duration (short: < 6, 6–7 h; reference: 7–8 h; long sleep: ≥ 8 h). Analyses were repeated after stratification by participants' sex, age, and BMI categories. We conducted sensitivity analysis by using the Asian criteria of overweight (BMI: 23–24 kg/m^2) and obesity (BMI ≥ 25 kg/m^2). For subgroup analyses, we defined SDB using AHI ≥ 15 (moderate or severe SDB) versus AHI < 15; short sleep duration was defined as having sleep < 6 versus ≥ 6 h. We further adjusted for BMI in analyses stratified by sex and age. In addition, we conducted sensitivity analysis by considering 95 individuals who were excluded from participating in the sleep examination due to active PAP use as having "moderate or severe" SDB. Those 95 PAP users were not, however, included in multivariable analyses that required measurement of sleep traits. We also examined the relative probabilities of self-reported doctor-diagnosed sleep apnea for Blacks, Hispanics, and Chinese as compared with Whites given a PSG-measured SDB. We also conducted sensitivity analyses by adjusting for one sleep disturbance (e.g., insomnia, SAS) for another (e.g., sleep duration, sleep quality) in related logistic regression models. Statistical analyses were performed using Statistical Analysis Software (version 9.3; SAS Institute, Cary, NC). The significance levels were set at P < 0.05 for two-sided analyses.

RESULTS

Of the 2,230 participants aged 54–93 y included in the study, 37.1% were White, 27.4% were Black, 23.7% were Hispanics, and 11.7% were Chinese. The distributions of sex and age were

Table 2—Sleep disturbances of study participants across racial/ethnic groups.

	White		Black		Hispanic		Chinese		
	n	% or mean (SD)	n	% or mean (SD)	n	% or mean (SD)	n	% or mean (SD)	P value [a]
Diagnosed sleep apnea, %									
No	738	89.2	551	90.0	485	92.0	253	96.6	0.002
Yes	89	10.8	61	10.0	42	8.0	9	3.4	
Total	827		612		527		262		
Habitual snoring, %									
No	530	64.0	390	63.7	267	50.6	149	56.9	< 0.001
Yes	298	36.0	222	36.3	261	49.4	113	43.1	
Total	828		612		528		262		
AHI (events/h), mean (SD)	734	13.3 (15.5)	572	14.9 (17.8)	487	16.6 (17.2)	241	16.0 (16.6)	0.005
SDB category, %									
Normal (AHI < 5)	273	37.2	209	36.5	139	28.5	81	33.6	0.024
Mild SDB (AHI = 5–14)	239	32.6	178	31.1	162	33.3	65	27.0	
Moderate SDB (AHI = 15–29)	131	17.9	100	17.5	100	20.5	52	21.6	
Severe SDB (AHI ≥ 30)	91	12.4	85	14.9	86	17.7	43	17.8	
Total	734		572		487		241		
Sleep apnea syndrome [b], %									
No	680	92.6	499	87.2	438	89.9	217	90.0	0.014
Yes	54	7.4	73	12.8	49	10.1	24	10.0	
Total	734		572		487		241		
Sleep duration (h), mean (SD)	787	6.85 (1.22)	590	6.05 (1.41)	496	6.56 (1.37)	229	6.35 (1.34)	< 0.001
Sleep duration category, %									
< 6 h	152	19.3	256	43.4	156	31.5	85	37.1	< 0.001
6–7 h	249	31.6	193	32.7	150	30.2	61	26.6	
7–8 h	271	34.4	97	16.4	124	25.0	64	28.0	
≥ 8 h	115	14.6	44	7.5	66	13.3	19	8.3	
Total	787		590		496		229		
Sleep maintenance efficiency (%), mean (SD)	787	91.4 (3.4)	590	90.3 (3.9)	496	90.5 (3.4)	229	90.7 (3.6)	< 0.001
Sleep quality [c], %									
Good	748	95.0	541	91.7	463	93.4	214	93.5	0.098
Poor	39	5.0	49	8.3	33	6.7	15	6.6	
Total	787		590		496		229		
Insomnia [d], %									
No	642	77.5	459	75.0	388	73.5	220	84.0	0.007
Yes	186	22.5	153	25.0	140	26.5	42	16.0	
Total	828		612		528		262		
Excessive daytime sleepiness [e], %									
No	734	88.7	497	81.2	456	86.4	233	88.9	< 0.001
Yes	94	11.4	115	18.8	72	13.6	29	11.1	
Total	828		612		528		262		

[a]Analysis of variance was conducted for continuous variables and chi-square test was conducted for categorical variables. [b]Sleep apnea syndrome was defined as having AHI ≥ 5 and the Epworth Sleepiness Scale (ESS) score > 10. [c]Sleep quality was defined as poor if the actigraphy-measured sleep maintenance efficiency < 85%, whereas sleep quality was defined as good if the sleep maintenance efficiency ≥ 85%. [d]The 5-item Women's Health Initiative Insomnia Rating Scale (WHIIRS) was used to define insomnia, with the total score of WHIIRS > 10 as having insomnia. [e]Excessive daytime sleepiness was assessed using the Epworth Sleepiness Scale (ESS) score > 10. AHI, apnea-hypopnea index; SD, standard deviation; SDB, sleep disordered breathing.

similar across racial/ethnic groups (Table 1). The mean of BMI was the highest among Blacks and Hispanics, and was the lowest among Chinese.

Overall, 9.0% of participants reported doctor-diagnosed sleep apnea. PSG showed that 33.8% had moderate or severe SDB (AHI ≥ 15), 15.0% had severe SDB (AHI ≥ 30), and 9.8% had SAS. Actigraphy showed that 30.9% had short sleep and 6.5% low sleep efficiency. Self-reported insomnia (23.4%) and

daytime sleepiness (13.9%) were prevalent. Sleep disturbances varied across racial/ethnic groups (Table 2). For instance, doctor-diagnosed sleep apnea was uncommon among Chinese, whereas habitual snoring and PSG-measured SDB were most common among Hispanics and Chinese; SAS was most prevalent among Blacks. The prevalence of short sleep varied from 43.4% (among Blacks) to 19.3% (among Whites). Chinese had the lowest prevalence of insomnia. Daytime sleepiness was the

Table 3—Logistic regression models: associations between race/ethnicity and sleep disturbances.

	Black versus White		Hispanic versus White		Chinese versus White	
	Unadjusted OR (95% CI)	Sex-, age-, and site-adjusted OR (95% CI)	Unadjusted OR (95% CI)	Sex-, age-, and site-adjusted OR (95% CI)	Unadjusted OR (95% CI)	Sex-, age-, and site-adjusted OR (95% CI)
Diagnosed sleep apnea	0.92 (0.65, 1.30)	0.96 (0.66, 1.40)	0.72 (0.49, 1.06)	0.99 (0.63, 1.57)	0.30 (0.15, 0.59)	0.51 (0.23, 1.11)
Habitual snoring	1.01 (0.82, 1.26)	0.93 (0.73, 1.17)	1.74 (1.39, 2.17)	1.64 (1.26, 2.13)	1.35 (1.02, 1.79)	1.41 (1.00, 1.98)
SDB category[a]						
Normal	Referent	Referent	Referent	Referent	Referent	Referent
Mild SDB	0.97 (0.75, 1.27)	1.03 (0.77, 1.36)	1.33 (1.00, 1.77)	1.58 (1.13, 2.20)	0.92 (0.63, 1.33)	1.01 (0.65, 1.55)
Moderate SDB	1.00 (0.73, 1.37)	1.06 (0.76, 1.50)	1.50 (1.08, 2.09)	1.96 (1.33, 2.91)	1.34 (0.89, 2.01)	1.23 (0.77, 1.98)
Severe SDB	1.22 (0.86, 1.73)	1.35 (0.93, 1.98)	1.86 (1.30, 2.66)	2.14 (1.40, 3.28)	1.59 (1.03, 2.47)	1.37 (0.81, 2.31)
Sleep apnea syndrome[b]	1.84 (1.27, 2.67)	1.78 (1.20, 2.63)	1.41 (0.94, 2.11)	1.47 (0.92, 2.35)	1.39 (0.84, 2.31)	1.25 (0.70, 2.21)
Sleep duration[c]						
< 6 h	4.71 (3.46, 6.39)	4.95 (3.56, 6.90)	2.24 (1.65, 3.05)	1.80 (1.26, 2.58)	2.37 (1.62, 3.46)	2.31 (1.48, 3.61)
6–7 h	2.17 (1.61, 2.92)	2.07 (1.51, 2.84)	1.32 (0.98, 1.77)	1.28 (0.91, 1.81)	1.04 (0.70, 1.53)	1.12 (0.71, 1.76)
7–8 h	Referent	Referent	Referent	Referent	Referent	Referent
≥ 8 h	1.07 (0.70, 1.62)	1.04 (0.67, 1.62)	1.25 (0.87, 1.82)	1.20 (0.77, 1.86)	0.70 (0.40, 1.22)	0.76 (0.40, 1.44)
Poor sleep quality[d]	1.74 (1.13, 2.68)	1.57 (1.00, 2.48)	1.37 (0.85, 2.20)	1.39 (0.80, 2.44)	1.34 (0.73, 2.49)	1.94 (0.93, 4.07)
Insomnia[e]	1.15 (0.90, 1.47)	1.11 (0.86, 1.45)	1.25 (0.97, 1.60)	1.28 (0.95, 1.72)	0.66 (0.46, 0.95)	0.66 (0.44, 1.00)
Daytime sleepiness[f]	1.81 (1.35, 2.43)	1.89 (1.38, 2.60)	1.23 (0.89, 1.71)	1.20 (0.83, 1.75)	0.97 (0.63, 1.51)	0.89 (0.54, 1.47)

[a]Based on polysomnography-measured data, multinomial logistic regression models were conducted, AHI < 5 served as the reference; mild SDB (AHI = 5–14), moderate SDB (AHI = 15–29), and severe SDB (AHI ≥ 30). [b]Sleep apnea syndrome was defined as having AHI ≥ 5 and the Epworth Sleepiness Scale (ESS) score > 10. [c]Based on actigraphy-measured data, multinomial logistic regression models were conducted, sleep duration 7–8 h served as the reference. [d]Sleep quality was defined as poor if the actigraphy-measured sleep maintenance efficiency < 85%, whereas good sleep quality was defined if the sleep maintenance efficiency ≥ 85%. [e]The 5-item Women's Health Initiative Insomnia Rating Scale as used to define insomnia, with the total score of WHIIRS > 10 as having insomnia. [f]Excessive daytime sleepiness was assessed using the Epworth Sleepiness Scale (ESS) score > 10. AHI, apnea-hypopnea index; CI, confidence interval; OR, odds ratio; SDB, sleep disordered breathing.

most common among Blacks and Hispanics, whereas it was similar for Whites and Chinese.

Across race/ethnic groups, men had age-adjusted mean AHI values that were 60–98% higher than values observed among women (Figure S1, supplemental material). Age-adjusted mean sleep duration varied by both race/ethnicity and sex, with the shortest sleep duration observed among Black men (5.76 h) and Black women (6.29 h) and the longest sleep among White women (7.01 h) (Figure S2, supplemental material).

Compared with Whites, Blacks had higher sex-, age-, and study site-adjusted odds of SAS (OR = 1.78; 95% CI: 1.20, 2.63), short sleep (OR = 4.95; 95% CI: 3.56, 6.90), poor sleep quality (OR = 1.57; 95% CI: 1.00, 2.48), and daytime sleepiness (OR = 1.89; 95% CI: 1.38, 2.60) (Table 3). Hispanics were 1.64 times as likely to report habitual snoring, 2.14 times as likely to have severe SDB, and 1.80 times as likely to have short sleep as compared with Whites. Although Chinese were 49% less likely to report doctor-diagnosed sleep apnea and 34% less likely to report insomnia, they were 37% more likely to have severe SDB and 131% more likely to have short sleep than Whites. Additional analyses of race/ethnicity variation in insomnia and SAS showed that additional adjustment for sleep duration and for sleep efficiency did not appreciably influence the variation in insomnia or SAS by race/ethnicity (data not shown in tables). For example, adjusting for sleep duration did not substantially alter the increased odds of SAS among Blacks as compared with Whites. The sex-, age-, and

site-adjusted OR changed from 1.78 (95% CI: 1.20, 2.63) to 1.52 (95% CI: 1.01, 2.29) when sleep duration was included in the model.

Age-, study site-, and BMI-adjusted ORs of SDB were statistically significantly greater for Chinese men and women compared to their White sex-specific counterparts (Figure 1A). The adjusted odds of short sleep was elevated for Black, Hispanic, and Chinese men and women, as compared with their White counterparts (Figure 1B). Chinese men had elevated odds of poor sleep quality as compared with White men (Figure 1C). Black men and Chinese men had elevated odds of daytime sleepiness compared with White men (Figure 1D). Black women had elevated odds of sleepiness as compared with White women. Overall, we observed no evidence of statistically significant effect modification by sex (P values for interaction terms were > 0.05).

We repeated sex-, study site-, and BMI-adjusted analyses stratified by age (Figure 2). Higher odds of SDB among Chinese (Figure 2A) and short sleep among Blacks (Figure 2B) were observed across all age groups. Compared with Whites, Hispanics aged 75–93 y tended to have elevated odds of SDB, although the interaction term was not statistically significant. There was no evidence of elevated odds of SDB among Hispanics in younger age groups. Racial/ethnic differences in short sleep duration were more pronounced among younger individuals. Middle-aged Hispanics and Chinese had higher odds of short sleep than Whites; this was not true for the oldest
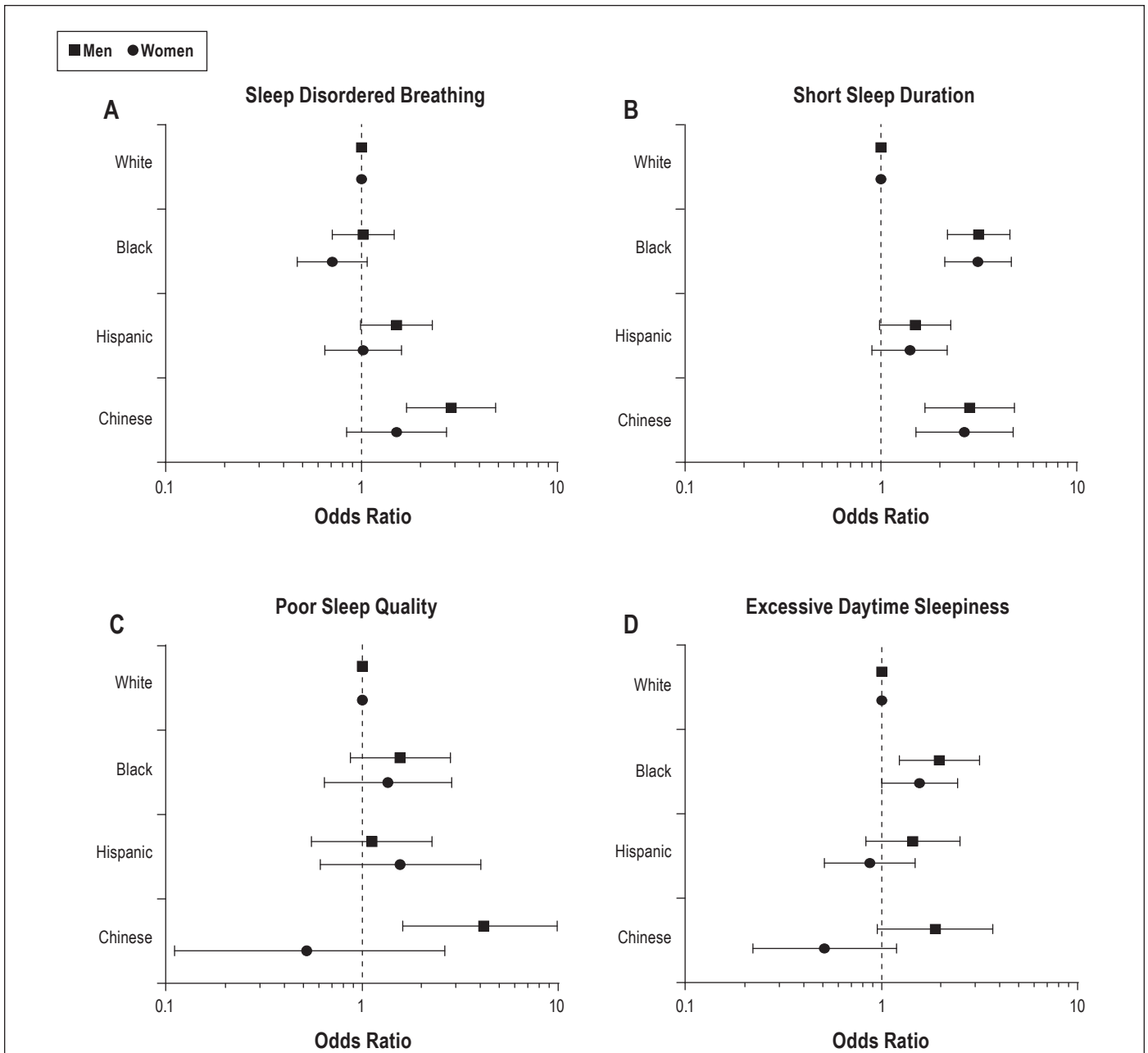
Figure 1—Age-, study site-, and body mass index-adjusted logistic regression models for associations between race/ethnicity and sleep disturbances, stratified by sex: the Multi-Ethnic Study of Atherosclerosis (MESA), 2010–2013. **(A)** Sleep disordered breathing: apnea-hypopnea index (AHI) ≥ 15 (reference: AHI < 15). **(B)** Short sleep duration: < 6 h versus ≥ 6 h. **(C)** Poor sleep quality (sleep efficiency < 85% versus ≥ 85%). **(D)** Excessive daytime sleepiness (the Epworth Sleepiness Scale score > 10 versus score ≤ 10).

group (P value for interaction = 0.045). The odds of poor sleep quality was elevated among middle-aged Blacks and Chinese when compared with their White counterparts (Figure 2C). Among Hispanics, the odds of poor sleep quality tended to be the highest in the oldest group. Across age groups, the odds of daytime sleepiness was higher among Blacks, but was similar for Hispanics and Chinese, as compared to their White counterparts (Figure 2D).

We conducted sex-, age-, and study site-adjusted analyses stratified by BMI categories (Figure 3). Chinese had higher odds of SDB than Whites irrespective of BMI categories (Figure 3A). Among non-obese individuals, Chinese had the

highest odds of SDB compared to Whites. Blacks, Hispanics, and Chinese had higher odds of short sleep than Whites irrespective of BMI categories (Figure 3B). Blacks with normal weight or obesity had higher odds of poor sleep quality than their White counterparts (Figure 3C). These variations in short sleep duration and poor sleep quality by race/ethnicity persisted with further adjustment for SDB and insomnia (data not shown). Within the stratum BMI of ≥ 30 kg/m², Blacks had higher odds of sleepiness than Whites (Figure 3D), although the interaction terms did not reach statistical significance. Sensitivity analyses using the Asian cut-points of obesity showed similar results (data not shown).
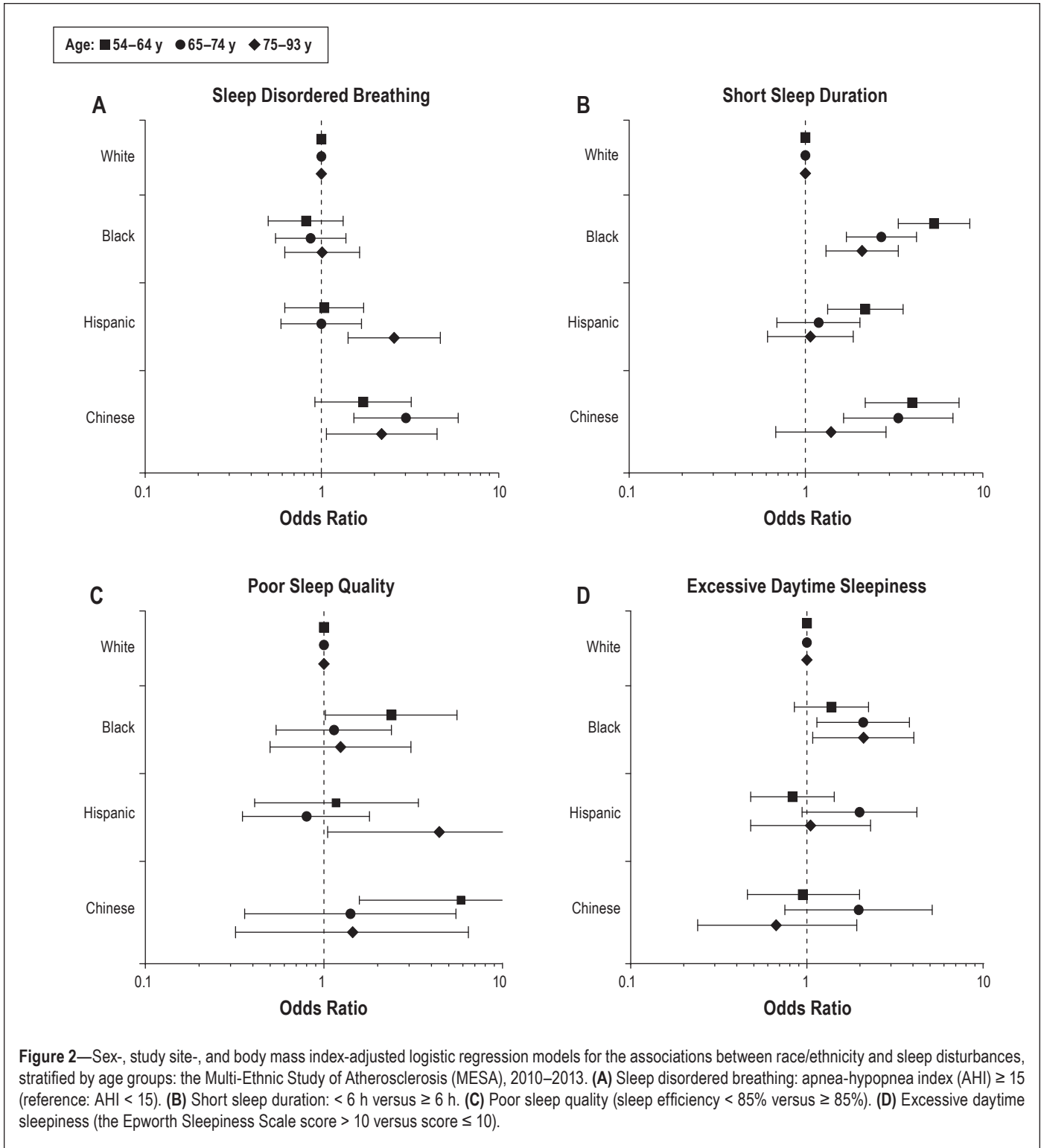
Figure 2—Sex-, study site-, and body mass index-adjusted logistic regression models for the associations between race/ethnicity and sleep disturbances, stratified by age groups: the Multi-Ethnic Study of Atherosclerosis (MESA), 2010–2013. **(A)** Sleep disordered breathing: apnea-hypopnea index (AHI) ≥ 15 (reference: AHI < 15). **(B)** Short sleep duration: < 6 h versus ≥ 6 h. **(C)** Poor sleep quality (sleep efficiency < 85% versus ≥ 85%). **(D)** Excessive daytime sleepiness (the Epworth Sleepiness Scale score > 10 versus score ≤ 10).

Among MESA participants, a total of 95 individuals (58 Whites, 14 Blacks, 21 Hispanics and 2 Chinese) were excluded from participating in the sleep examination due to their active PAP use. When including these individuals in the sensitivity analysis, classifying them as having "moderate or severe" SDB, we found that the prevalence of moderate or severe SDB increased from 30.3% to 35.1% for Whites, 32.3% to 34.1% for Blacks, 38.2% to 41.0% for Hispanics, and 39.4% to 39.9% for Chinese, respectively. When considering these 95 individuals

as having "severe" SDB, the prevalence of severe SDB was increased from 12.4% to 18.5% for Whites, 14.9% to 17.0% for Blacks, 17.7% to 21.4% for Hispanics, and 17.8% to 18.5% for Chinese, respectively (Table S2, supplemental material). The multinomial logistic regression models showed that after including the 95 prior PAP users in the "severe SDB" category, the relative odds of SDB prevalence increased among Hispanics compared to Whites (sex-, age-, and site-adjusted OR = 1.76; 95% CI: 1.20, 2.57). However, assigning PAP users
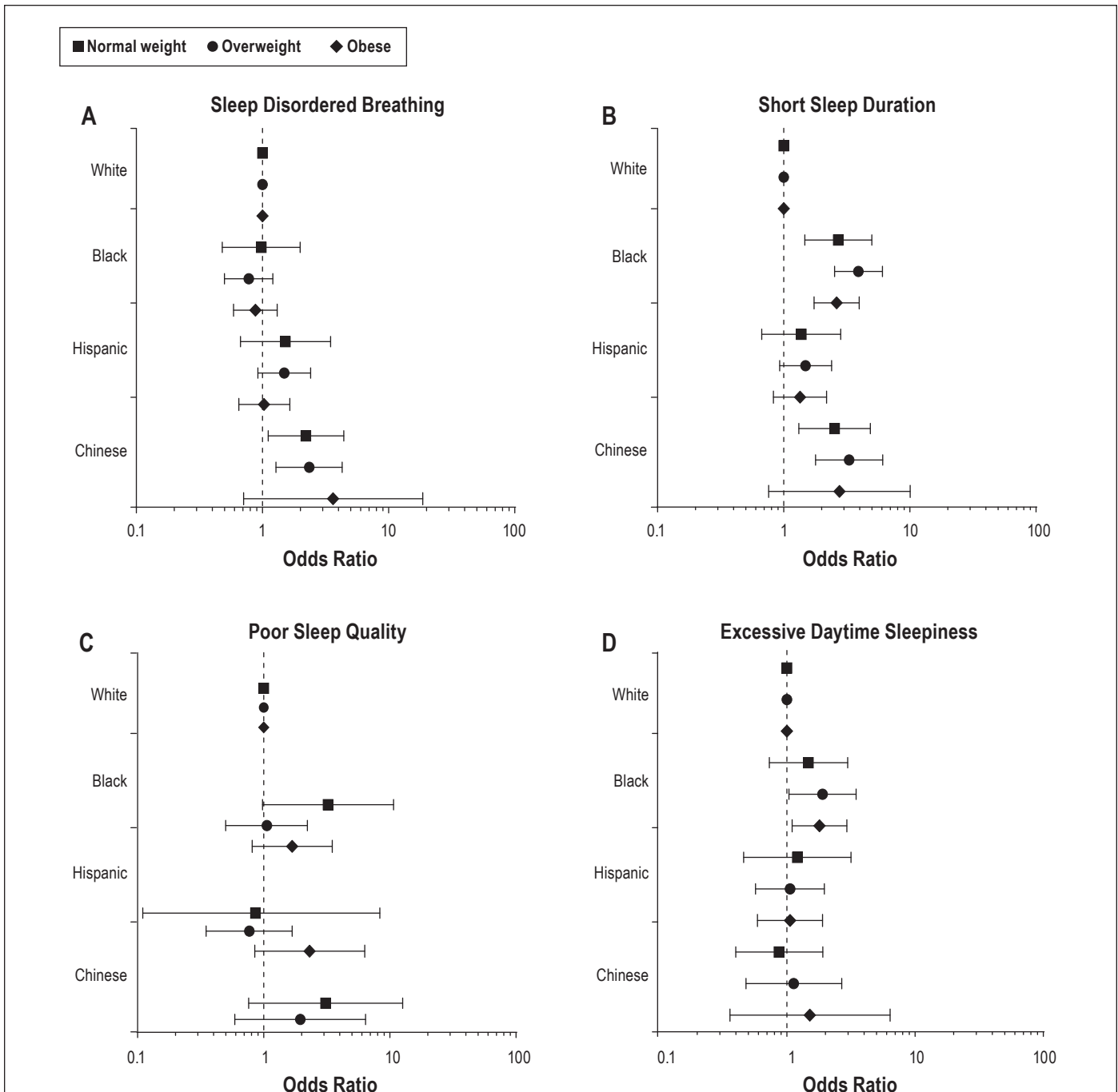
Figure 3—Sex-, age-, and study site-adjusted logistic regression models for the associations between race/ethnicity and sleep disturbances, stratified by body mass index (BMI): the Multi-Ethnic Study of Atherosclerosis (MESA), 2010–2013. **(A)** Sleep disordered breathing: apnea-hypopnea index (AHI) ≥ 15 (reference: AHI < 15). **(B)** Short sleep duration: < 6 h versus ≥ 6 h. **(C)** Poor sleep quality (sleep efficiency < 85% versus ≥ 85%). The Chinese group had no data for the obese group. **(D)** Excessive daytime sleepiness (the Epworth Sleepiness Scale score > 10 versus score ≤ 10). Normal weight: BMI < 25 kg/m^2; Overweight: BMI = 25–29 kg/m^2. Obese: BMI ≥ 30 kg/m^2.

as having severe SDB and including these in the analytical dataset attenuated the associations related to Chinese race (sex-, age-, and site-adjusted OR = 1.18; 95% CI: 0.72, 1.95), although the OR was significantly elevated after adjustment for BMI (sex-, age-, site-, and BMI-adjusted OR = 3.13; 95% CI: 1.80, 5.44) (Table S3, supplemental material).

As shown in Table S4 (supplemental material), approximately 10.0% of Whites with PSG-measured SDB (AHI ≥ 15) reported having a doctor-diagnosed SDB. The corresponding

conditional probabilities for self-reported doctor-diagnosed SDB (given MESA PSG-measured SDB) among Blacks, Hispanics, and Chinese were 16.2%, 14.5%, and 7.4%, respectively. In other words, 84–93% of MESA participants with PSG-measured moderate or more severe SDB did not report a doctor-diagnosed sleep apnea. The percent of doctor-diagnosed sleep apnea among individuals with severe SDB (AHI ≥ 30) was slightly higher, ranging from 9.3% (Chinese) to 18.8% (Blacks). Compared to Whites with PSG-measured SDB, Blacks and

Hispanics were more likely to have a doctor-diagnosed sleep apnea, whereas Chinese were less likely to have a doctor-diagnosed sleep apnea, although these associations were not statistically significant.

DISCUSSION

To our knowledge, this is the first study that has systematically evaluated objective measures of SDB, short sleep duration, and poor sleep quality, as well as subjective measures of habitual snoring, insomnia, and daytime sleepiness in a multiethnic US sample that includes Chinese Americans. Findings from this direct multiple comparison of sleep disturbances showed a high prevalence of sleep disturbances and undiagnosed sleep apnea among racial/ethnic minority groups, as well as significant variation in SDB, short sleep duration, SAS, sleep quality, and sleepiness across racial/ethnic groups. Hispanics and Chinese had higher odds of measured SDB, with Chinese differences most evident after adjusting for BMI. However, Chinese had the lowest prevalence of doctor-diagnosed sleep apnea. Short sleep duration was significantly more prevalent among Blacks, Hispanics, and Chinese as compared with Whites. Overall, Blacks had the shortest sleep duration and also had higher odds of SAS, poor sleep quality, and daytime sleepiness as compared with Whites. A higher prevalence of sleepiness among Blacks was not explained by differences in sleep duration or SDB. Notably, these associations remained evident after adjustment for sex, age, study site, and BMI. These findings indicate that sleep disturbances such as short sleep duration and SDB are more frequent among racial/ethnic minorities than Whites, and suggest that sleep disturbances may contribute to health disparities among US adults.

Sleep Disordered Breathing (SDB)

SDB is influenced by a complex array of risk factors that affect airway patency, some of which may reflect environmental influences, genetic factors, and others.[34] Family and pediatric studies indicate that among children and young adults, SDB is more common among Blacks than among Whites,[35–37] with racial/ethnic differences partly explained by exposures to factors that aggregate in disadvantaged neighborhoods, including tobacco smoke. SDB is also highly heritable.[38] Obesity is a strong risk factor for SDB, although more than half of the genetic factors associated with SDB are estimated to be independent of obesity.[39,40] Data from Asia also point to a high prevalence of SDB among Chinese, Japanese, Korean, and Indian populations.[41–44] Several potential mechanisms may link race/ethnicity to SDB, including variation in craniofacial anatomy and body fat distribution. Asians have more pronounced craniofacial skeletal abnormalities than Whites for a given degree of SDB severity.[45,46] Blacks may be predisposed to SDB through the influence of obesity and enlarged upper airway soft tissues,[21] as well as through exposures to adverse social and physical environments.

Few studies have directly compared SDB prevalence across multiple racial/ethnic groups. Although some investigators have reported no racial/ethnic difference in SDB,[47] others report that Blacks and Hispanics have a high prevalence of severe SDB.[29,48,49] In MESA, where SDB was comprehensively assessed using PSG, we observed a high prevalence of moderate or more severe SDB among all groups, which was significantly elevated among Chinese (39.4%) and Hispanics (38.2%) as compared with Whites. Although consideration of differences in obesity attenuated some of racial/ethnic variation, the odds of SDB among Chinese increased after adjustment for BMI. Furthermore, among participants with BMI ≥ 25 kg/m^2, the SAS prevalence was higher among Blacks, Hispanic, and Chinese than Whites. As SDB has been implicated as a risk factor for CVD, stroke, diabetes, and premature mortality,[3,4,6] our findings underscore the need to consider unrecognized sleep apnea in middle-aged and older adults, with potential value in developing new strategies to screen and treat Chinese group.

Blacks had the highest prevalence of SAS (12.8%), but did not have a higher prevalence of doctor-diagnosed sleep apnea or PSG-measured SDB than Whites. This finding likely reflects the high prevalence of daytime sleepiness (18.8%) among Blacks. Whether Blacks with even low levels of AHI (5 or higher) are more susceptible to sleepiness than other racial/ethnic groups, and thus have a true higher prevalence of SAS, or if instead the sleepiness associated with low AHI levels reflects insufficient sleep due to factors other than SDB, is unclear. However, adjusting for sleep duration did not substantially alter the increased odds of SAS prevalence among Blacks.

The prevalence of moderate or severe SDB was as much as tenfold higher than reported doctor-diagnosed sleep apnea. In fact, between 84% and 93% of individuals with AHI levels moderately or severely elevated (and thus candidates for sleep apnea treatment), were undiagnosed. Although data from the past 15 y indicate that there is a high prevalence of undiagnosed and untreated sleep apnea,[8] these recent data collected in a cohort receiving regular health feedback information through MESA examinations suggest that this problem persists, and is particularly salient for some groups, such as middle-aged and older Chinese, who may not be routinely recognized to be at risk for SDB. In MESA, those who participated versus not participated in the sleep study did not differ in regards to likelihood of having doctor-diagnosed sleep apnea; however the pattern did vary by racial/ethnic groups. There were discrepancies between self-reported sleep apnea and polysomnographically measured sleep apnea (SDB), which were the most prominent for Chinese participants.

Sleep Duration

Short sleep duration has been identified as a risk factor for obesity, hypertension, diabetes, and CVD.[50,51] In MESA, 32% of participants had actigraphy-measured sleep with < 6 h per night. We found that objectively measured short sleep duration was more frequent in all three minority groups and was observed in both men and women and across age and BMI strata. We also found that racial/ethnic differences in short sleep duration were more pronounced among younger individuals. The shortest sleep duration was observed among Black men, who slept on average 75 min less than White women. Black women slept on average 43 min less than White women. These findings are consistent with a prior national survey using questionnaire data of Whites and Blacks aged 18–85 y.[15] Our findings are also consistent with data from an actigraphy-based study of Chicago Whites and Blacks aged 38–50 y in the Coronary

Artery Risk Development in Young Adults (CARDIA) study showing that sleep duration was the shortest for Black men (5.1 h) and the longest for White women (6.7 h).[20] Our data further extend these results by showing that short sleep duration also occurred in an older sample of Chinese and Hispanics and was not explained by insomnia or SAS. Among Blacks, we showed that an increased prevalence of short sleep also occurred across all age groups, and that Blacks had a high prevalence of poor sleep quality and sleepiness. There is a need for research that examines factors that may contribute to reduced sleep duration, such as family burden, employment status, stress, and environmental disturbances.

Long sleep duration, usually identified through self-report, has been associated with numerous adverse health outcomes.[50] With the use of 7-day actigraphy, we found a relatively low prevalence of longer sleep (≥ 8 h), and little evidence for racial/ethnic variation. Although in the general population ≥ 8 h of sleep is usually considered as normal sleep duration, this middle-aged and older population in MESA had few participants (2%) with longer sleep duration ≥ 9 h. Further research is needed to understand differences between self-reported as compared to actigraphy-based sleep assessments and their association with health outcomes, especially among racial/ethnic minority populations.

Poor Sleep Quality

Poor sleep quality (reduced sleep efficiency) reflects an increased time awake after sleep onset. This may be due to any number of factors that disturb sleep, such as physiological arousals or environmental disturbances. We found that Black and Chinese men were more likely to have poor sleep quality than their White counterparts, even after adjustment for BMI, SDB, and insomnia. A finding of higher odds of poor sleep quality in racial/ethnic minorities is of clinical significance given prior reports linking poor sleep quality to elevated blood pressure,[52] metabolic disturbances,[53] and cognitive deficits.[54]

Insomnia

Insomnia is common in the general population, especially among women and older adults.[55] Approximately 48% of Americans have insomnia occasionally, whereas 22% experience insomnia every or almost every night.[55] Insomnia and poor sleep quality have been associated with stress, anxiety, and depression.[56,57] Telephone survey data from the Behavioral Risk Factor Surveillance System found that Asian Americans reported the least sleep complaints, and Blacks and Hispanics reported fewer sleep complaints than Whites.[9] We found that fewer Chinese reported insomnia symptoms and daytime sleepiness, whereas more Blacks, particularly those who were obese, reported insomnia and sleepiness than Whites. Our use of validated measures of self-reported sleep problems reduces, but did not eliminate, the likelihood of differential reporting across racial/ethnic groups. Further research is needed to address potential differences in objective and subjective measures of sleep disturbances across population groups.

Sex and Age Variation

A number of studies have reported sex and age differences in SDB and other sleep disturbances.[2,11,13,14,19,41] We also explored whether racial/ethnic variation in sleep disturbances differed by sex and age groups. Our findings confirm prior research showing a higher prevalence of SDB in men than in women. Furthermore, we found that Chinese men had higher prevalence of SDB than White men despite a relatively lower prevalence of doctor-diagnosed sleep apnea. Racial/ethnic minority men may underutilize health services,[58] and thus, our findings indicate that special efforts to improve screening in these groups may be warranted. Most of the racial/ethnic differences in sleep disturbances were observed across the age range of 54–93 y. This suggests that sleep health disparities exist in both middle-aged and older Americans.

Strengths and Limitations

Our study has important strengths including the relatively large sample size, the community-based sampling of a multi-ethnic cohort with considerable heterogeneity. Of note, sleep disturbances were assessed using valid objective measures including PSG- and actigraphy-based methodologies, and self-reported sleep disturbances were assessed using well-established questionnaires. The diverse study sample allowed us to assess the prevalence and odds of sleep disturbances across groups defined by race/ethnicity and within strata defined by sex, age, and BMI. In addition, we considered study site and other sleep disturbances when examining a specific sleep disturbance.

Despite these strengths, several limitations merit consideration. First, the lack of temporality makes it difficult to determine whether BMI, a covariate we adjusted for, served as a confounder or mediator of relationships of interest. Further studies are needed to examine the roles of sleep and obesity in the racial/ethnic differences using longitudinal data. Second, we cannot rule out the fact that our findings may be at least, in part, influenced by selection bias. The estimates of SDB prevalence are limited by factors that influence participation in epidemiologic studies. When the MESA cohort was first assembled (10 y prior to the sleep exam), individuals with clinically apparent CVD were excluded. Therefore, those at high risk for early onset CVD may have been underrepresented in the sleep examination. Although the participation rate in the sleep examination was relatively high, the possibility of selective participation may exist. However, sleep symptoms and health characteristics were generally similar for participants and nonparticipants in the sleep examination. Because of the difficulty associated with studying individuals on chronic PAP use, 2% of the MESA sample (n = 95) did not undergo a sleep examination. A sensitivity analysis that assumed those individuals who had moderate or severe SDB was conducted and showed overall similar prevalence rates as the primary analysis other than attenuation of the SDB risk among Chinese. Third, we did not include information on occupation (e.g., night shift work), the use of sleep medications, depressive symptoms, or urban versus rural residence in this article. This information may help identify more specific environmental (e.g., noise and types of jobs) or comorbidities that influence racial/ethnic differences in sleep. Finally, although we had an overall large sample size, we had limited statistical power for some subgroup analyses, particularly those aimed at examining the odds of SDB and poor sleep quality among Chinese participants according to BMI categories.

SUMMARY

Analyses from this well-described, community-based multi-ethnic cohort identified a high prevalence of sleep disturbances in middle-aged and older men and women. Using objective sleep testing, moderate or more severe SDB and short sleep duration each were found in more than 30% of the cohort. The largest observed racial/ethnic differences were for short sleep duration. Blacks were five times, Hispanics were 1.8 times, and Chinese were 2.3 times as likely to have short sleep duration as compared with Whites after adjustment for sex, age, and study site. SDB was more prevalent in Hispanics and in Chinese, especially Chinese-American men, a group rarely recognized to be at increased risk for SDB. In fact, sleep apnea had been diagnosed in only 7% to 16% of individuals with an elevated AHI. Our findings underscore the high prevalence of undiagnosed sleep disturbances in middle-aged and older adults, and identify racial/ethnic disparities that include differences in short sleep duration, SDB, and daytime sleepiness, as well as the likely differences in recognition of SDB. These data support a need for further research to better understand the bases for sleep health disparities that can identify opportunities for improving health across population groups.

ABBREVIATIONS

AHI, apnea-hypopnea index
BMI, body mass index
CARDIA, Coronary Artery Risk Development in Young Adults
CI, confidence interval
CVD, cardiovascular disease
ECG, electrocardiogram
EEG, electroencephalography
EMG, electromyography
ESS, Epworth Sleepiness Scale
MESA, Multi-Ethnic Study of Atherosclerosis
OR, odds ratio
PAP, positive airway pressure
PSG, polysomnography
SAS, sleep apnea syndrome
SD, standard deviation
SDB, sleep disordered breathing
WHIIRS, Women's Health Initiative Insomnia Rating Scale

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Table S1—Comparison of sociodemographic and health characteristics at the Multi-Ethnic Study of Atherosclerosis (MESA) exam 5 between participants with and without sleep data at exam 5.

MESA Exam 5 (n = 4,716)	Participants without Sleep Data	Participants with Sleep Data	P Value
%	56.4	43.6	
Sex, %			
Men	46.9	46.4	0.704
Women	53.1	53.6	
Age, mean (SD), years	71.0 (9.6)	68.4 (9.1)	< 0.001
Age category, %			
54–64 y	29.8	40.1	< 0.001
65–74 y	31.0	31.9	
75–93 y	39.3	28.1	
Race/ethnicity, %			
White	44.5	36.1	< 0.001
Black	25.5	28.0	
Hispanic	19.1	23.9	
Chinese	10.9	12.1	
Study site, %			
Forsyth, NC	19.3	14.6	0.001
New York, NY	16.6	17.9	
Baltimore, MD	13.4	14.7	
St. Paul, MN	15.5	17.4	
Chicago, IL	18.5	18.7	
Los Angeles, CA	16.7	16.7	
Country of birth, %			
US-born	72.9	65.5	< 0.001
Foreign-born	27.1	34.5	
Education, %			
< High school	13.7	15.1	0.119
High school	18.3	16.3	
> High school	68.0	68.6	
Smoking status, %			
Never	51.1	55.1	0.026
Former smoker	41.2	38.4	
Current smoker	7.6	6.6	
Cigarette smoking, %			
Never	43.5	47.2	0.025
Former smoker	48.1	45.7	
Current smoker	8.4	7.1	

MESA Exam 5 (n = 4,716)	Participants without Sleep Data	Participants with Sleep Data	P Value
Alcohol drinking, %			
No	57.0	56.8	0.873
Yes	43.0	43.2	
Body mass index, mean (SD), kg/m^2	28.3 (5.8)	28.7 (5.5)	0.056
Obesity status, %			
Body mass index < 25	30.2	27.4	0.107
Body mass index = 25–29	36.7	37.7	
Body mass index ≥ 30	33.1	34.9	
Hypertension , %			
No	38.0	43.3	< 0.001
Yes	62.1	56.7	
Diabetes, %			
Normal	59.0	59.8	0.851
Impaired Fasting Glucose	20.9	20.3	
Untreated and treated diabetes	20.2	19.9	
Heart attack (Myocardial infarction) , %			
No	97.9	98.0	0.715
Yes	2.2	2.0	
Self-reported asthma, %			
No	96.6	96.3	0.170
Yes	3.1	3.7	
Don't know	0.2	0.1	
Self-reported emphysema/chronic obstructive pulmonary disease , %			
No	97.0	98.2	0.028
Yes	2.5	1.6	
Don't know	0.5	0.2	
Self-reported doctor-diagnosed sleep apnea at Exam 2, %			
No	95.2	95.8	0.530
Yes	3.7	3.1	
Don't know	1.2	1.1	

Table S2—Prevalence of polysomnography-measured sleep disordered breathing plus prior positive airway pressure use (n = 95) across racial/ethnic groups.

SDB Definition	Total n	Total %	White n	White %	Black n	Black %	Hispanic n	Hispanic %	Chinese n	Chinese %	P Value
Moderate or severe SDB											
AHI ≥ 15	688	33.8	222	30.3	185	32.3	186	38.2	95	39.4	0.007
AHI ≥ 15 plus prior PAP use	783	36.8	277	35.1	200	34.1	209	41.0	97	39.9	0.053
Difference	95	3.0	55	4.8	15	1.8	23	2.8	2	0.5	
Severe SDB											
AHI ≥ 30	305	15.0	91	12.4	85	14.9	86	17.7	43	17.8	0.043
AHI ≥ 30 plus prior PAP use	400	18.8	146	18.5	100	17.0	109	21.4	45	18.5	0.325
Difference	95	3.8	55	6.1	15	2.2	23	3.7	2	0.7	

AHI, apnea-hypopnea index; PAP, positive airway pressure; SDB, sleep disordered breathing.

Table S3—Multinomial logistic regression models: associations between race/ethnicity and sleep disordered breathing plus prior positive airway pressure use.

	Black vs. White		Hispanic vs. White		Chinese vs. White	
	Sex-, age- & site-adjusted	Sex-, age-, site-, & BMI-adjusted	Sex-, age- & site-adjusted	Sex-, age-, site-, & BMI-adjusted	Sex-, age- & site-adjusted	Sex-, age-, site-, & BMI-adjusted
SDB Category [a]	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Normal	Referent	Referent	Referent	Referent	Referent	Referent
Mild SDB	1.03 (0.78, 1.37)	0.79 (0.59, 1.06)	1.58 (1.13, 2.20)	1.32 (0.94, 1.86)	1.01 (0.65, 1.55)	1.35 (0.87, 2.11)
Moderate SDB	1.07 (0.76, 1.50)	0.73 (0.51, 1.05)	1.95 (1.32, 2.89)	1.48 (0.99, 2.24)	1.22 (0.76, 1.97)	2.08 (1.26, 3.43)
Severe SDB+PAP use	1.11 (0.78, 1.56)	0.65 (0.45, 0.96)	1.76 (1.20, 2.57)	1.14 (0.75, 1.74)	1.18 (0.72, 1.95)	3.13 (1.80, 5.44)

[a] SDB was defined as: normal, AHI < 5; mild SDB, AHI = 5–14; moderate SDB, AHI = 15–29; severe SDB, AHI ≥ 30. BMI, body mass index; CI, confidence interval; OR, odds ratio; PAP, positive airway pressure; SDB, sleep disordered breathing.

Table S4—Percent and odds of study participants with self-reported diagnosed sleep apnea according to measured sleep disordered breathing across racial/ethnic groups.

Race/Ethnicity	PSG-Measured SDB in MESA (%)	
	AHI ≥ 15	AHI ≥ 30
White	10.0	14.3
Black	16.2	18.8
Hispanic	14.5	18.6
Chinese	7.4	9.3
	OR (95% CI)	OR (95% CI)
Unadjusted		
Black versus White	1.75 (0.97, 3.16)	1.39 (0.63, 3.10)
Hispanic versus White	1.54 (0.84, 2.80)	1.37 (0.62, 3.05)
Chinese versus White	0.72 (0.30, 1.75)	0.62 (0.19, 2.01)
Adjusted for Sex and Age		
Black versus White	1.80 (1.00, 3.26)	1.42 (0.63, 3.19)
Hispanic versus White	1.55 (0.85, 2.85)	1.40 (0.62, 3.13)
Chinese versus White	0.68 (0.28, 1.67)	0.63 (0.19, 2.07)
Adjusted for Sex, Age, and Study Site		
Black versus White	1.77 (0.93, 3.37)	1.02 (0.41, 2.54)
Hispanic versus White	2.04 (0.98, 4.28)	1.89 (0.69, 5.23)
Chinese versus White	1.21 (0.44, 3.34)	0.97 (0.24, 3.89)
Adjusted for Sex, Age, and Body Mass Index		
Black versus White	1.62 (0.88, 2.96)	1.29 (0.57, 2.93)
Hispanic versus White	1.41 (0.76, 2.62)	1.34 (0.59, 3.03)
Chinese versus White	1.15 (0.45, 2.94)	0.96 (0.28, 3.36)

AHI, apnea-hypopnea index; CI, confidence interval; MESA, Multi-Ethnic Study of Atherosclerosis; OR, odds ratio; PSG, polysomnography; SDB, sleep disordered breathing.
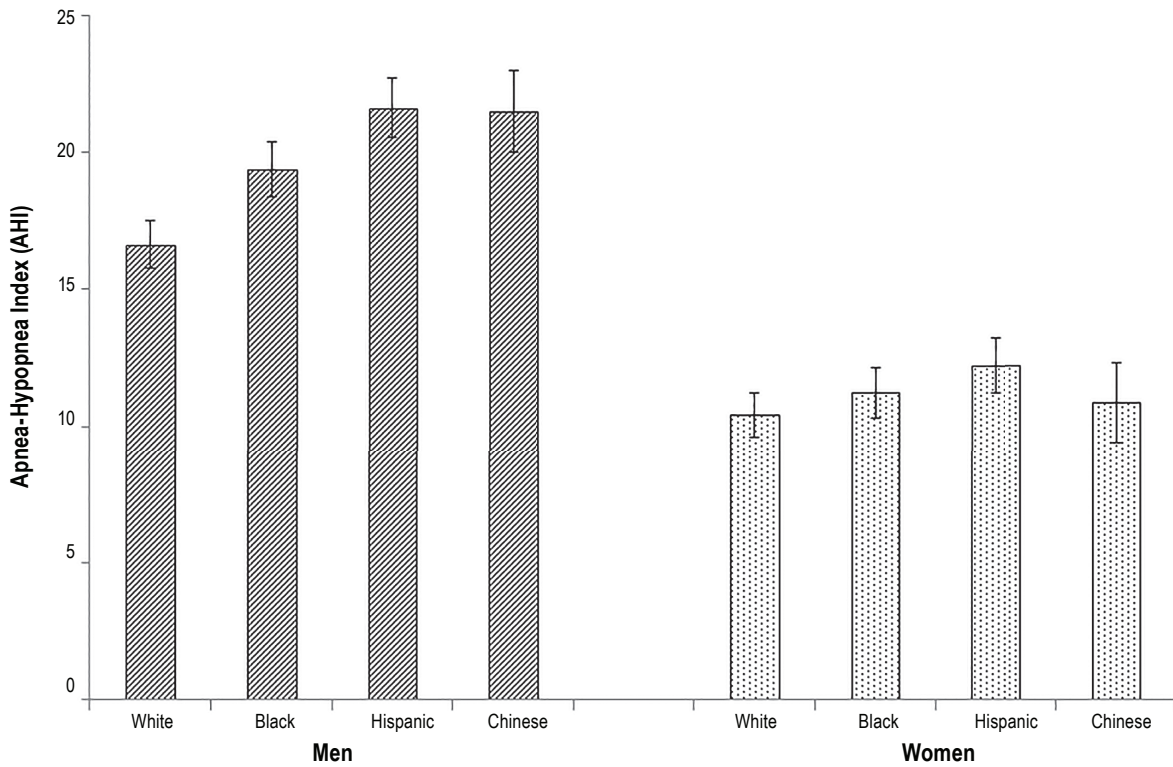
Figure S1—Age-adjusted apnea-hypopnea index across sex and racial/ethnic groups in the Multi-Ethnic Study of Atherosclerosis (MESA), 2010–2013. Age-adjusted means of apnea-hypopnea index (AHI) with standard errors were presented. The general linear model was conducted to generate least-square means and standard errors. P values for the comparisons of the differences in AHI between groups were less than 0.001. AHI, apnea-hypopnea index.
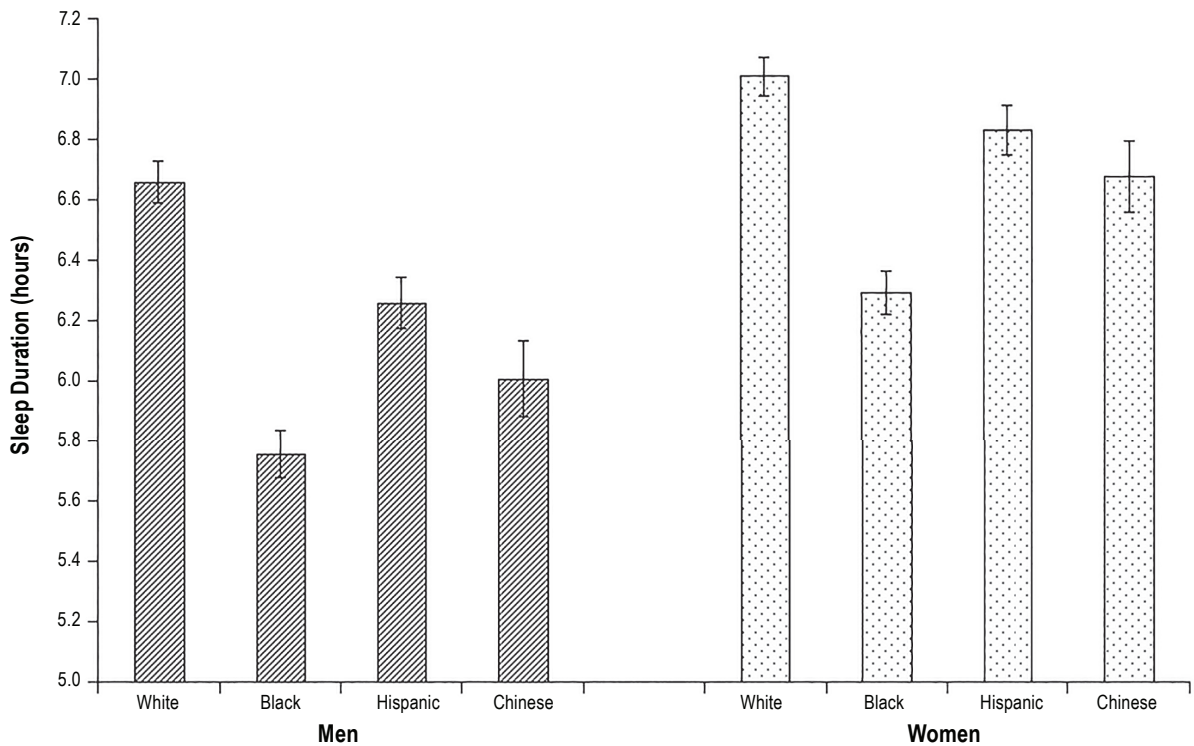

Figure S2—Age-adjusted sleep duration (hours) across sex and racial/ethnic groups in the Multi-Ethnic Study of Atherosclerosis (MESA), 2010–2013. Age-adjusted means of sleep duration with standard errors were presented. The general linear model was conducted to generate least-square means and standard errors. P values for the comparisons of the differences in sleep duration between groups were less than 0.001.