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Does Race-Ethnicity Moderate the Relationship between CPAP Adherence and Functional Outcomes of Sleep in US Veterans with Obstructive Sleep Apnea Syndrome?

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SCIENTIFIC INVESTIGATIONS

Background: Little is known about the association of race-ethnicity and the relationship of continuous positive airway pressure (CPAP) adherence with functional outcomes of sleep in American samples with obstructive sleep apnea syndrome (OSAS). This retrospective study examines whether race-ethnicity moderates the relationship between CPAP adherence and functional outcomes of sleep in OSAS.

Methods: Over 4 months, consecutive OSAS patients had CPAP data downloads and completed questionnaires (demographics, Functional Outcomes of Sleep Questionnaire [FOSQ], Epworth Sleepiness Scale [ESS], Insomnia Severity Index [ISI]) at the Miami VA sleep center. Medical diagnoses and polysomnography data were obtained from medical record. CPAP adherence was measured as mean daily hours of use. Hierarchical regression modeling was used to explore the differential impact of race-ethnicity and CPAP adherence on functional outcomes of sleep.

Results: Two hundred twenty-seven veterans (93% male, age 59 ± 11 years) were included; 142 (63%) participants self-reported as white or Hispanic, and 85 participants (37%) as black. Hierarchical regression analyses failed to show main effects for race-ethnicity or CPAP use and FOSQ scores; however, the interaction of race-ethnicity with CPAP adherence was significantly associated with the total FOSQ ($p = 0.04$), Social ($p = 0.02$), and Intimacy ($p = 0.01$) subscale scores. For blacks, in adjusted analyses, CPAP adherence was positively associated with Social and Intimacy FOSQ subscales; however, no significant relationship was noted between CPAP use and FOSQ scores in whites/Hispanics.

Conclusions: Race-ethnicity may moderate the relationship between CPAP adherence and some functional outcomes of sleep; however, further studies are needed.

Keywords: veterans, race-ethnicity, quality of life, functional outcomes, sleep apnea, positive airway pressure, adherence

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Reduced health-related quality of life (HRQOL) resulting from sleep disturbances have been observed in race-ethnic minorities in American population-based studies.[1] For example, in the Sleep Heart Health Study, blacks with habitual snoring, insomnia symptoms, or excessive daytime sleepiness (EDS) had significantly poorer physical health quality of life than whites. One of the causes of EDS is untreated obstructive sleep apnea syndrome (OSAS), which results in fragmented sleep, repeated sympathetic hyperarousal, and intermittent hypoxia.[2] Furthermore, OSAS has been associated with lower HRQOL including impaired functional status, which is an individual's ability to perform necessary daily tasks to fulfill usual life role.[3-5] Despite the higher prevalence of OSAS in American minority samples when compared to whites, there are few reports comparing race-ethnic groups in functional status in diverse American samples with OSAS.[6-12]

Functional status in obstructive sleep apnea is commonly measured using the Functional Outcomes of Sleep Questionnaire (FOSQ). The FOSQ assesses the impact of daytime sleepiness on the ability to perform activities of daily living.[7] Similar to generic QOL measures, multiple domains of functioning are assessed such as activity level and general productivity. In addition, functional outcomes specifically related to reduced or disrupted sleep (e.g. vigilance, intimacy) are included in the scale. Even though this instrument was developed and validated in multi-race cohorts with OSAS, race-ethnic comparisons were not reported.[7] Although most studies have reported higher levels

BRIEF SUMMARY

Current Knowledge/Study Rationale: Although studies have documented improvement in functional outcomes of sleep with continuous positive airway pressure (CPAP) treatment, to our knowledge, none have examined race-ethnicity as a potential moderator of the relationship between CPAP use and functional status in American samples with obstructive sleep apnea syndrome (OSAS). As race-ethnic differences exist for CPAP use and other covariates influencing functional outcomes of sleep, we performed a cross-sectional analysis to examine if race-ethnicity moderated the relationship between CPAP adherence and the functional outcomes of sleep questionnaire (FOSQ) in US veterans with OSAS.

Study Impact: After adjusting for multiple covariates, race-ethnicity moderated the relationship between CPAP adherence and the total, Social, and Intimacy FOSQ subscales. These data suggest that the impact of CPAP use on some functional outcomes of sleep may be conditional upon race-ethnicity; however, longitudinal studies are needed to replicate these findings.

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of EDS in blacks than whites, a recent study using the 2007-2008 NHANES data found that blacks had lower EDS than whites.[13-17] Therefore, these data suggest that there may be significant race-ethnic differences in functional outcomes associated with OSAS.[13,15-17] Furthermore, this could be clinically important, as the impact of OSAS on an individual's daytime symptoms may be one determinant of regular continuous positive airway pressure (CPAP) use, the first-line treatment for OSAS.[18]

In predominantly white samples, regular CPAP use reduces daytime sleepiness and improves functional outcomes of sleep in a linear, dose-dependent manner.[19-21] For example, in 149 participants (88% white) with moderate or severe OSAS recruited from 7 US and Canadian sleep centers, Weaver and colleagues showed dose-response effects of 3 months of CPAP treatment and improvements in the FOSQ.[19] In another predominantly white cohort in Australia with moderate to severe OSAS (n = 174), Antic et al. reported similar results after 3 months of CPAP therapy.[20] Similar findings were shown in the CPAP Apnea Trial North American Program (CATNAP) randomized clinical trial with sleepy participants (n = 239, 78% white) who had mild to moderate OSAS.[21] Participants receiving 8 weeks of CPAP treatment showed significant improvements in the total FOSQ and most of its subscales, while participants receiving placebo had unchanged FOSQ scores. Importantly, none of these prior studies have adjusted for insomnia symptoms, a frequent comorbidity of OSAS, which can worsen EDS and further depress daytime function.[22] It is currently unknown if race-ethnicity moderates the relationship between CPAP treatment and functional outcomes of sleep.

At our center, blacks use CPAP on average about 1 hour less daily than whites after adjusting for demographics, OSAS severity, comorbid insomnia symptoms, and other covariates.[23] In addition, blacks have been reported to have more disruptive sleeping environments than whites, which may result in less restorative sleep in the former.[6] Furthermore, because black race has been associated with greater OSAS severity and lower CPAP adherence than white race, it seems plausible that blacks, on average, would have worse functional outcomes of sleep than whites.[6,23-25]

The aims of this study were (1) to examine whether race-ethnic differences exist in functional outcomes of sleep between blacks and whites with OSAS treated with CPAP, and (2) to determine whether race-ethnicity moderates the relationship between treatment adherence and functional outcomes of sleep in a diverse sample of US veterans with OSAS. First, we hypothesized that blacks would have worse functional outcomes of sleep than whites. Second, we hypothesized that the effects of CPAP use on functional outcomes of sleep would be attenuated in blacks compared to whites.

METHODS

Participants

We performed a retrospective, cross-sectional analysis of adult white, black, and Hispanic veterans with OSAS who attended the Miami VA Healthcare System (VAHS) Sleep Clinic from July 2011 to October 2011 for a scheduled CPAP adherence visit. Inclusion criteria included: (1) white, black, or Hispanic race-ethnicity, (2) OSAS diagnosis and CPAP prescription at the Miami VAHS within the last 5 years, (3) completion of study questionnaires, and (4) possession of CPAP ≥ 7 days. Veterans were excluded if they (1) had previous surgery for OSAS, (2) were prescribed supplemental oxygen, or (3) were of mixed race-ethnicity (i.e., black Hispanic).

Procedure

As part of their routine adherence visit to the Miami VAHS, veterans with OSAS treated with CPAP complete questionnaires regarding demographics, medical comorbidities, and residual sleep symptoms. Race-ethnic group was determined by self-report (non-Hispanic white, non-Hispanic black, Hispanic/Latino, or Other). Participants were asked to complete validated questionnaires to determine functional outcomes of sleep, subjective daytime sleepiness, and insomnia severity (described in questionnaires section below). Anthropometric measures (height and weight) were recorded on the day of their clinic visit and used to calculate the body mass index (BMI). Questionnaires were completed in English, as all veterans were fluent English speakers. Objective CPAP adherence was verified as described in CPAP adherence section below. The Miami VA Healthcare System Institutional Review Board approved the protocol.

Assessments

Questionnaires

Demographic questionnaires assessed participant age on the day of clinical visit, gender, marital status (married or partnered vs single or widowed), highest educational attainment (high school graduate or lower, some college, or college graduate or higher), and social habits (smoking status, alcohol consumption, caffeine use). Medical and psychiatric comorbidities and medications were obtained from questionnaires and review of medical records. Weighted medical comorbidities were calculated using the Charlson Comorbidity Index (CCI).[26]

Functional status was assessed with the Functional Outcomes of Sleep Questionnaire (FOSQ). The FOSQ is a 30-item reliable, valid tool of general quality of life in disorders of excessive sleepiness.[7] Items 1-26 are phrased in the form "Do you have difficulty [specified action or situation] because you are too sleepy or tired?" The last 4 items examining intimacy ask "Has your [specified sexual function] been affected because you are too sleepy or tired?" Likert scale responses range from 1 (extreme difficulty) to 4 (no difficulty). Questions assess 5 domains, including general productivity (8 items), social outcome (2 items), activity level (9 items), vigilance (7 items), and intimacy (4 items). Subscales are determined by averaging the number of answered items within each domain. The total FOSQ is calculated by averaging the existing subscales and multiplying by 5. The total FOSQ score ranges between 5 and 20, with lower scores representing greater impairment in functioning. The FOSQ has been found to be capable of discriminating between normal participants and untreated OSAS patients.[7]

Subjective daytime sleepiness was determined using the Epworth sleepiness scale (ESS), with 8 items rated on a scale of 0-3 and higher scores indicating a greater propensity to fall asleep in different situations.[27] An ESS score > 10 defined excessive daytime sleepiness.

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Participants completed the insomnia severity index (ISI), a 7-item instrument measuring the individual's perception of his or her insomnia. The first 3 items assess early, middle, and late insomnia complaints, while the last 4 items assess the daytime consequences of insomnia. The total scores range from 0 to 28, with higher scores indicating greater insomnia severity. Its internal consistency, concurrent validity, and sensitivity to clinical improvements are well established.[28]

Polysomnography and OSAS Diagnosis

All veterans completed diagnostic and titration PSGs performed at the Miami VAHS. Details concerning technical equipment, polysomnography protocol, and scoring have been previously described.[23] All individuals completed (1) an in-lab diagnostic PSG followed by a manual titration PSG (n = 78), (2) an in-lab split-night PSG (n = 133), or (3) an unattended diagnostic portable PSG followed by a manual titration PSG (n = 16). Scoring was performed manually by a certified sleep technologist, using 30-s epochs and standardized scoring techniques.[29] Hypopnea scoring followed the recommended definition (≥ 30% reduction in nasal pressure relative to baseline associated with ≥ 4% oxygen desaturation).

CPAP Treatment

All veterans accepting CPAP treatment complete a standardized 30-min mask-fitting and equipment educational session by our sleep-certified respiratory technologists at the time of CPAP distribution. They are also provided with printed information about OSAS, its health consequences, and CPAP troubleshooting techniques. Patients completing split-night or in-lab titration PSG received CPAP units (Remstar M series with C-flex and heated humidifier, Philips-Respironics, Murrysville, PA) fixed at the prescribed pressure obtained from the titration PSG and distributed by our laboratory staff. All devices contained software (Philips-Respironics Encore Pro 2) that recorded CPAP mask-on time onto a microchip within a Secure Digital (SD) memory card.

CPAP Adherence

After CPAP distribution, veterans were scheduled for standard clinical follow up for CPAP adherence. These visits occurred at varying intervals but usually after 3-6 months of treatment initiation and then annually. Individuals were encouraged to return to our sleep center earlier if they encountered ongoing difficulties. The sample included recently diagnosed individuals having their initial CPAP adherence download as well as those who were long-term CPAP users who may have had prior downloads. Adherence measures were averaged over all days since initial CPAP distribution (mean of 17 ± 16 months). On the day of the clinical visit, the following variables were collected from CPAP SD memory cards: prescribed CPAP pressure, days since CPAP distribution (duration of ownership), % of days used, % of days used > 4 h, mean daily use, and residual AHI.

Data Analysis

Demographic and clinical characteristics, CPAP adherence variables, and questionnaire responses were compared between whites/Hispanics and blacks. In agreement with other studies, we have reported that whites and Hispanics are not statistically different in their CPAP adherence.[23,25] In addition, no statistically significant differences were found in the total FOSQ and all subscales between Hispanics and whites. Furthermore, most of our Hispanic veterans were born in the US and are highly acculturated.[12] For these reasons, we combined whites and Hispanics race-ethnic groups.

Data are reported as means and SDs for continuous variables and frequencies (%) for categorical variables. Continuous and categorical data were compared among race-ethnic groups using Student t-test or χ^2, respectively. Mean daily hours of CPAP use was used as the primary adherence measure. The assumptions for use of parametric inferential statistics were met for all variables.

Linear regression analyses were performed (1) to provide comparison of the adjusted mean differences between race-ethnic groups on the FOSQ, and (2) to determine if race-ethnicity moderated (interacted with) the relationship between CPAP adherence and FOSQ scores. The analyses proceeded as follows: first, we compared means and missing values of individual items in the FOSQ across race-ethnicities to detect race-ethnic differences in response patterns. Second, zero-order correlations between CPAP use and FOSQ scores were determined for the entire sample and then by race-ethnic group. Then, hierarchical linear regression modeling was used to explore the association of predictor variables (race-ethnicity and CPAP adherence) with total FOSQ score and its subscales. Black race was analyzed referent to white/Hispanic race-ethnicity. Covariates for the FOSQ scores were chosen based on previous research on health-related QOL and sleep-specific QOL.[1,3-5,22,30,31] In addition, significant race-ethnic differences in measured health habits (smoking, alcohol use, caffeine) which could influence daytime sleepiness were also added as covariates. Models were constructed sequentially by entering variables in the following order: (1) covariates (age, gender, BMI, marital status, education, daily caffeine use, Charlson index, posttraumatic stress disorder, mood disorder, AHI, insomnia symptoms, and CPAP treatment duration), (2) black race-ethnicity, (3) CPAP adherence (mean daily h), and (4) black race-ethnicity by CPAP adherence interaction. These interaction terms were of primary interest to determine if race-ethnicity moderated the relationship CPAP adherence and functional outcomes of sleep. Simple slope analyses were performed to estimate the association between mean daily CPAP use and FOSQ scores across race-ethnic groups.

For all models, multicollinearity among predictors was examined by scrutinizing their Pearson correlations, variance inflation factors, eigenvalues, and condition indexes. For all analyses, $p < 0.05$ was defined as statistically significant. Statistical analyses were performed with SPSS Statistics 21.0 (SPSS, Chicago, IL). Simple slopes and **Figure 1** were generated with PROCESS.[32]

RESULTS

Characteristics of Study Participants

During the 4-month period of data collection, 280 veterans attended the Miami VA CPAP adherence clinic. Fifty-three veterans were excluded (38 for skipping the FOSQ, 3 for prior OSAS surgery, 7 for using supplemental oxygen, 5 for mixed

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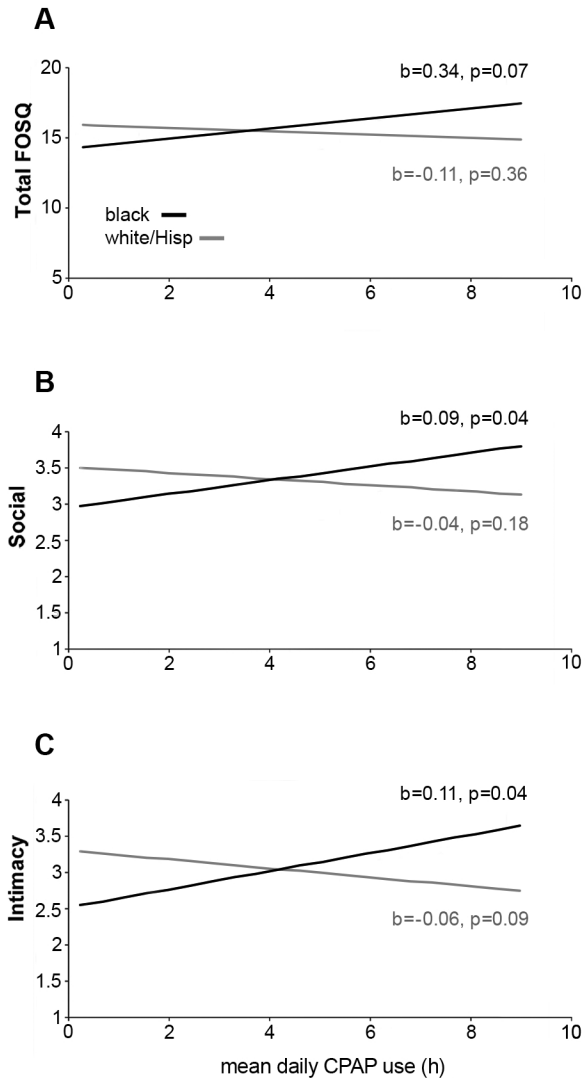
Figure 1—Regression lines for fully adjusted model.



A significant black race by daily CPAP use interaction was noted for total FOSQ **(A)** (p = 0.04), Social subscale **(B)** (p = 0.02), and Intimacy subscale **(C)** (p = 0.01). In blacks, the simple slope for the relationship between CPAP use and total FOSQ (b = 0.34, p = 0.07) was not significantly different from zero, but was significantly different for the relationship between CPAP use and Social (b = 0.09, p = 0.04) and Intimacy (b = 0.11, p = 0.04) subscales. In whites/Hispanics, the simple slopes for the relationship between CPAP use and total FOSQ (b = -0.11, p = 0.36), Social (b = -0.04, p = 0.18), and Intimacy (b = -0.06, p = 0.09) subscales were not significantly different from zero.

race-ethnicity). There were 20 black, 13 Hispanic, 15 white, and 5 black Hispanic individuals excluded. Two hundred twenty-seven veterans (93% male, age 59 ± 11 years) were included. One hundred forty-two (63%) participants self-reported as white or Hispanic, and 85 participants (37%) as black.

Demographic and Clinical Comparisons by Race-Ethnicity

Descriptive characteristics of the study sample are presented in **Table 1**. Blacks were more likely to be single/widowed compared to whites/Hispanics. In addition, blacks had significantly lower levels of education and were less likely to use daily caffeine than whites/Hispanics. Finally, blacks had significantly higher prevalence of hypertension and higher mean Charlson index (weighted medical comorbidities) compared to whites/Hispanics.

Polysomnography and CPAP Adherence Measures by Race-Ethnicity

Participants had a mean AHI of 39 ± 30 events/h of sleep and were prescribed a mean CPAP pressure of 9.8 ± 2.8 cm H_2O (**Table 2**). There were no significant race-ethnic differences in mean AHI, prescribed CPAP pressure, or CPAP residual AHI at clinical follow-up. Averaged across all participants, CPAP had been distributed 17 ± 16 months prior to their adherence visit. The entire cohort used CPAP on 57% ± 34% of the nights, with mean daily use of 3.1 ± 2.6 hours. The duration of CPAP ownership was significantly shorter in blacks compared to whites/Hispanics (**Table 2**). Blacks used CPAP on significantly fewer days and used CPAP over 1 h less daily than whites/Hispanics.

FOSQ and other Questionnaire Responses by Race-Ethnicity

Missing responses for individual FOSQ items ranged from 0-10% across all veterans. The most commonly unanswered question was item 27 ("Has your intimate or sexual relationship been affected because you are too sleepy or tired?"). No race-ethnic differences were observed in the frequency of missing data in any individual FOSQ item.

At clinical follow-up, blacks had significantly lower mean FOSQ Social and Intimacy subscales than whites/Hispanics (**Table 3**). There were no other significant race-ethnic differences observed in unadjusted FOSQ total score or FOSQ subscales. Finally, blacks had significantly greater mean Epworth Sleepiness Scale and insomnia symptoms (first 3 items of the ISI) compared to whites/Hispanics.

Correlations of Daily CPAP Use and FOSQ Scores by Race-Ethnicity

For all participants combined, mean daily hours of CPAP use were significantly and positively correlated with total FOSQ and Activity level subscale (**Table 4**). However, when the sample was divided into race-ethnic groups, a different pattern emerged. For whites/Hispanics, mean hours of CPAP therapy was not significantly correlated with the total FOSQ score or any of its subscales. In contrast, for blacks, mean daily hours of CPAP use were significantly and positively correlated with the total FOSQ score and all its subscales with the exception of the General Productivity subscale. As a follow up to these findings, we proceeded with a regression analysis to explore the race-ethnic interactions in these correlations.

Linear Regression Models

The significant contributions from the steps for each FOSQ model are highlighted in **Table 5**. In all FOSQ models, the aggregated covariates were significantly associated with the outcome and explained 18.8% to 28.6% of the observed variability. In contrast to the unadjusted results, differences between whites/Hispanic and Black race-ethnicity were not found on total FOSQ or any subscale when covariates were added to the model. Similarly, daily CPAP use by itself did not predict any FOSQ scores. However, the interaction of black race with CPAP

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Table 1—Demographic and clinical characteristics by race-ethnicity.

	All (n = 227)	White/Hispanic (n = 142)	Black (n = 85)	p value
Demographics				
Male, %	93	93	93	0.99
Age, years	59 ± 11	59 ± 12	58 ± 10	0.66
BMI, kg/m^2	33 ± 5	33 ± 5	33 ± 5	0.96
Education, %				**< 0.001**
High school or lower	28	20	42	
Some college	33	31	36	
College grad or greater	35	44	21	
Marital Status, %				**0.03**
Single or widowed	39	34	48	
Married or partnered	61	66	52	
Social habits, %				
Current smoker	19	18	21	0.53
Daily alcohol use	11	12	8	0.19
Daily caffeine use	64	77	41	**< 0.001**
Medical comorbidities, %				
Hypertension	77	73	85	**0.04**
Diabetes	36	33	41	0.22
Heart disease	18	20	15	0.40
Stroke	6	4	9	0.12
Mood disorder	51	50	52	0.80
PTSD	28	25	34	0.13
Charlson Index	1.7 ± 1.9	1.5 ± 1.7	2.1 ± 2.2	**0.03**

Data presented as means ± SD or frequencies (%). Frequencies are rounded to nearest integer and may not add to 100%. Bolded values are significant ($p < 0.05$). BMI, body mass index; PTSD, posttraumatic stress disorder.

Table 2—Comparisons of OSAS severity and CPAP adherence by race-ethnicity.

	All (n = 227)	White/Hispanic (n = 142)	Black (n = 85)	p value
Polysomnography				
AHI (events/h)	39 ± 30	40 ± 29	38 ± 31	0.32
CPAP adherence download				
CPAP pressure (cm H_2O)	9.8 ± 2.8	9.7 ± 2.7	9.9 ± 2.9	0.65
Residual AHI (events/h)	5.5 ± 5.1	5.5 ± 4.8	5.7 ± 5.6	0.72
CPAP ownership (months)	17 ± 16	18 ± 17	13 ± 15	**0.04**
Days used (%)	57 ± 34	63 ± 34	47 ± 31	**< 0.001**
Daily use (h)	3.1 ± 2.6	3.6 ± 2.7	2.1 ± 2.1	**< 0.001**

Data presented as mean ± SD or frequency (%). Frequencies are rounded to nearest integer and may not add to 100%. Bolded values are significant ($p < 0.05$). AHI, apnea-hypopnea index; CPAP, continuous positive airway pressure.

Table 3—Comparisons of questionnaires by race-ethnicity.

	All (n = 227)	White/Hispanic (n = 142)	Black (n = 85)	p value
FOSQ scores				
Total	15.20 ± 3.88	15.50 ± 3.57	14.71 ± 4.32	0.14
General productivity	3.08 ± 0.80	3.13 ± 0.77	2.99 ± 0.86	0.22
Social	3.28 ± 0.88	3.37 ± 0.80	3.11 ± 0.98	**0.04**
Activity level	2.92 ± 0.80	2.94 ± 0.78	2.88 ± 0.84	0.59
Vigilance	2.97 ± 0.84	3.00 ± 0.82	2.91 ± 0.89	0.40
Intimacy	2.95 ± 1.06	3.07 ± 0.99	2.75 ± 1.15	**0.03**
Epworth Sleepiness Scale	10.14 ± 5.62	9.58 ± 5.50	11.08 ± 5.73	**0.04**
ISI Items1-3	5.33 ± 3.12	4.96 ± 2.99	5.94 ± 3.25	**0.03**

Data presented as mean ± SD. Bolded values are significant ($p < 0.05$). FOSQ, functional outcomes of sleep questionnaire; ISI, insomnia severity index.

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Table 4—Pearson correlations of daily CPAP use with FOSQ scores by race-ethnicity.

	All (n = 227)	p value	White/Hispanic (n = 142)	p value	Black (n = 85)	p value
FOSQ scores						
Total	**0.153**	**0.02**	0.052	0.54	**0.270**	**0.01**
General productivity	0.122	0.07	0.047	0.58	0.207	0.06
Social	0.117	0.09	-0.009	0.91	**0.263**	**0.02**
Activity level	**0.204**	**< 0.01**	0.155	0.07	**0.290**	**< 0.01**
Vigilance	0.127	0.06	0.053	0.53	**0.237**	**0.03**
Intimacy	0.119	0.08	-0.020	0.82	**0.289**	**0.01**

Bolded values are significant (p < 0.05). CPAP, continuous positive airway pressure; FOSQ, functional outcomes of sleep questionnaire.

Table 5—Summary of hierarchical regression analyses of covariates, race-ethnicity, CPAP adherence, and race-ethnicity by CPAP use interaction on FOSQ scores.

	FOSQ Total [a]	General Productivity [b]	Social [c]	Activity Level [d]	Vigilance [e]	Intimacy [f]
Steps	**Δ F, Δ R^2**	**Δ F, Δ R^2**	**Δ F, Δ R^2**	**Δ F, Δ R^2**	**Δ F, Δ R^2**	**Δ F, Δ R^2**
1) Covariates	**6.23, 0.256**	**4.18, 0.188**	**4.62, 0.211**	**7.23, 0.286**	**5.03, 0.220**	**4.39, 0.203**
2) Black race [†]	1.55, 0.012	1.49, 0.012	2.89, 0.023	1.38, 0.010	0.64, 0.005	2.60, 0.021
3) CPAP daily use (h)	0.032, 0.000	0.010, 0.000	0.102, 0.000	0.88, 0.003	0.91, 0.000	0.70, 0.003
4) Black by CPAP use	**4.78, 0.018**	2.83, 0.011	**6.49, 0.026**	2.73, 0.010	1.54, 0.006	**7.56, 0.030**

[†] Referent to white/Hispanic; [a] N = 227; [b] N = 219; [c] N = 216; [d] N = 215; [e] N = 218; [f] N = 211. Bolded values are significant (p < 0.05). Covariates included age, gender, marital status, education, caffeine use, body mass index, Charlson index, posttraumatic stress disorder, mood disorder, apnea-hypopnea index, insomnia symptoms, and CPAP treatment duration (months). FOSQ, functional outcomes of sleep questionnaire; CPAP, continuous positive airway pressure.

use significantly predicted the total FOSQ, Social, and Intimacy subscales. This last interaction term explained an additional 1.8% to 3.0% of the variability in the FOSQ scores. Within the models for total FOSQ, Social, and Intimacy subscales, insomnia was the only significant covariate. Insomnia symptoms were negatively associated (p < 0.001) with these outcomes. Regression coefficients for the overall models are presented in **Table 6**.

The significant interactions of black race with CPAP adherence for some FOSQ outcomes indicate that the relationship between CPAP adherence and FOSQ is moderated by race-ethnicity. Specifically, significant moderation was found for the total FOSQ (p = 0.04), Social (p = 0.02), and Intimacy (p = 0.01) scores (**Table 6**, **Figure 1**). We further probed the significant race by CPAP adherence interactions by testing the simple slopes of the relationship between CPAP use and FOSQ scores for each race-ethnic group. In whites/Hispanics, none of the simple slopes were significantly different from zero (total FOSQ [b = -0.11, 95% CI: -0.35-0.13; p = 0.36], Social [b = -0.04, 95% CI: -0.10-0.02; p = 0.18], and Intimacy [b = -0.06, 95% CI: -0.13-0.01; p = 0.09]). In blacks, the simple slope for the relationship between CPAP use and total FOSQ (b = 0.34, 95% CI: -0.05-0.71; p = 0.07) was not significantly different from zero. The significant interaction for total FOSQ resulted from the divergent slopes on the 2 race-ethnic groups but the simple slopes tests did not show that these statistically different from zero for either group. However, the simple slopes were significant for the Social (b = 0.09, 95% CI: 0.01-0.18; p = 0.04) and Intimacy (b = 0.11, 95% CI: 0.01-0.23; p = 0.04) subscales. In blacks, greater CPAP adherence was associated with higher Social and Intimacy FOSQ subscales; however, no significant relationship was noted between CPAP use and FOSQ scores in whites/Hispanics.

DISCUSSION

Our study results support the growing importance of considering individuals' race-ethnicity when assessing the relationship of CPAP treatment adherence and functional outcomes in OSAS patients. Currently, there are limited data about race-ethnic differences in CPAP use and functional outcomes of sleep.[10,11,19,21,33,34] We have previously reported the race-ethnic differences in CPAP adherence in this cohort.[23] The overall mean daily CPAP use of our sample was relatively poor, but within the range of reported American samples.[12,33-35] For blacks, CPAP use was significantly correlated with the total FOSQ and 4 of its 5 subscales (**Table 4**). In contrast, for whites/Hispanics, CPAP adherence was not significantly correlated to any of the FOSQ scores. In hierarchical regression analyses, after adjusting for demographics, BMI, medical/psychiatric comorbidities, social habits, AHI, and CPAP treatment factors, mean differences in FOSQ were no longer found for race-ethnicity. This was likely due to the significant covariates (**Table 5**). Additionally, mean daily CPAP use was no longer associated with FOSQ scores. However, by including the CPAP use by race interaction term, the moderation of CPAP use and FOSQ by race-ethnicity was revealed for the total score and Social and Intimacy subscales. Follow up testing of these interactions using simple slopes showed that the relationship between mean daily CPAP use and FOSQ scores was positive in blacks but unrelated for whites/Hispanics. Our data are novel in that (1) they

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Table 6—Overall hierarchical regression model of FOSQ scores.

					Model
FOSQ Total [a]	**b**	**SE**	**β**	**p**	**R^2 = 0.285**
Intercept	15.2	0.25			
Black [†]	-0.35	0.57	-0.05	0.51	
CPAP use (h)	-0.11	0.12	-0.10	0.36	
Black by CPAP use (h)	**0.48**	**0.22**	**0.16**	**0.04**	
Social [c]	**b**	**SE**	**β**	**p**	**R^2 = 0.261**
Intercept	3.27	0.06			
Black [†]	-0.18	0.13	-0.10	0.15	
CPAP use (h)	-0.04	0.03	-0.12	0.18	
Black by CPAP use (h)	**0.13**	**0.05**	**0.20**	**0.02**	
Vigilance [e]	**b**	**SE**	**β**	**p**	**R^2 = 0.232**
Intercept	2.97	0.07			
Black [†]	-0.01	0.12	-0.01	0.92	
CPAP use (h)	-0.02	0.03	-0.07	0.38	
Black by CPAP use (h)	0.06	0.05	0.10	0.22	

					Model
General Productivity [b]	**b**	**SE**	**β**	**p**	**R^2 = 0.211**
Intercept	3.08	0.05			
Black [†]	-0.06	0.12	-0.04	0.58	
CPAP use (h)	-0.02	0.03	-0.08	0.35	
Black by CPAP use (h)	0.08	0.05	0.13	0.09	
Activity Level [d]	**b**	**SE**	**β**	**p**	**R^2 = 0.308**
Intercept	2.91	0.05			
Black [†]	0.07	0.11	0.05	0.50	
CPAP use (h)	-0.01	0.02	-0.01	0.97	
Black by CPAP use (h)	0.07	0.05	0.12	0.10	
Intimacy [f]	**b**	**SE**	**β**	**p**	**R^2 = 0.257**
Intercept	3.09	0.09			
Black [†]	-0.25	0.15	-0.12	0.10	
CPAP use (h)	-0.06	0.04	-0.16	0.09	
Black by CPAP use (h)	**0.18**	**0.07**	**0.21**	**0.01**	

[†] Referent to white/Hispanic; [a] N = 227; [b] N = 219; [c] N = 216; [d] N = 215; [e] N = 218; [f] N = 211. Bolded values are significant (p < 0.05). CPAP use refers to mean daily hours of therapy. Analyses were adjusted for age, gender, marital status, education, caffeine use, body mass index, Charlson index, posttraumatic stress disorder, mood disorder, apnea-hypopnea index, insomnia symptoms, and CPAP treatment duration (months). FOSQ, functional outcomes of sleep questionnaire; CPAP, continuous positive airway pressure.

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were collected in a well-represented, diverse American clinical sample, (2) our models controlled for important covariates (i.e., insomnia symptoms), and (3) we determined that the effect of mean daily CPAP use on some functional outcomes of sleep may be conditional upon a veteran's race-ethnicity.

CPAP Effects on Functional Outcomes of Sleep

Many clinical studies of OSAS report improvements in the total FOSQ with CPAP treatment, but fewer report the effects of treatment on the individual FOSQ subscales.[10,11,19-21,33,34,36] Our cohort's unadjusted mean total FOSQ at clinical follow up (15.2 ± 3.9) falls between baseline values (untreated moderate-severe OSAS: 14.7 ± 2.9) and values for participants treated with CPAP 2-4 hours nightly for 3 months (16.8 ± 2.7).[19,20,34] In contrast, our cohort (older and with lower daily CPAP use than prior samples) had total and FOSQ subscale scores that approximated values of participants with untreated OSAS (**Table 3**).[10,11,21,34] Overall, these data suggest that many veterans returning to our CPAP clinic have impaired functional outcomes of sleep.

Unadjusted Correlations between CPAP Adherence and Functional Outcomes of Sleep

For all veterans, only the total FOSQ and Activity level subscale were significantly correlated to CPAP use (**Table 4**). In a longitudinal study where slightly more than half the participants were black (57%) with mean AHI of 44 ± 36 events/h, Ye et al. reported a correlation of 0.288 between CPAP use and the total FOSQ score after 7 days of CPAP treatment.[33] Despite a much longer treatment period, we found a similar correlation between CPAP use and the total FOSQ score in blacks (r = 0.270) but no significant correlation in whites/Hispanics (r = 0.052). Interestingly, when our sample was separated into race-ethnic groups, significant associations only existed for black participants. For blacks, all the FOSQ subscales were significantly correlated to CPAP adherence, but no relationship between FOSQ scores and CPAP use was noted for whites/Hispanics. For blacks, CPAP use was moderately, positively associated with FOSQ scores. To our knowledge, the finding of race-ethnic differences in the correlations between CPAP use and functional outcomes is novel and merits further exploration.

The Influence of CPAP Adherence on Functional Outcomes of Sleep Was Moderated by Race-Ethnicity

Collapsed across the race-ethnic groups, there was no significant relationship between CPAP use and FOSQ scores in the adjusted models (**Tables 5, 6**). Despite the absence of main effects for black race-ethnicity or CPAP use and FOSQ scores, race-ethnicity moderated the relationship between CPAP use and FOSQ scores (total, Social, and Intimacy) in blacks. Above and beyond the variability accounted for by the covariates, the black race by CPAP use interaction explained an additional 1% to 3% of the variability in the total score, Social, and Intimacy FOSQ scores (**Tables 5, 6**). As our complete models left the majority (69% to 79%) of the variability in the FOSQ scores unexplained, there are many other potential contributors to race-ethnic differences in functional outcomes of sleep that deserve further study.

Interestingly, the unadjusted significant correlations of the Vigilance and Activity level subscales with CPAP use among blacks were no longer significant in our fully adjusted model. Controlling for insomnia symptoms seemed to have more influence on Vigilance and Activity level functional outcomes than the Social and Intimacy subscales (which remained significant; **Tables 4, 5**). In the social functioning domains (Social and Intimacy), the finding of the association of CPAP adherence and functional outcomes in blacks is above and beyond that due to insomnia symptoms. Previous studies have shown that insomnia symptoms are related to poorer health-related quality of life and

daytime functioning.[37-39] Our results show similar findings in patients with OSAS, where comorbid insomnia symptoms are associated with several sleep-related functional outcomes. Similar to our data, a recent large study found that comorbid insomnia symptoms were associated with worse health-related quality of life in men with OSAS.[37] A second significant covariate whose inclusion affected the Activity level subscale was mood disorder diagnosis. As these comorbid conditions are common in OSAS, further exploration of the association of insomnia, mood, and functional outcomes in OSAS patients seems warranted.[22,23]

We found that race-ethnicity moderated the association of CPAP adherence on FOSQ total score, Social, and Intimacy subscales. Contrary to our hypothesis, probing these significant interactions revealed that the slopes for the relationship between daily CPAP use and Social and Intimacy function was positively related for blacks, but there was no association for whites/Hispanics in the controlled model (**Figure 1**). The significant findings for the total FOSQ ($b = 0.34$, $p = 0.07$) likely resulted from the significant Social and Intimacy subscales. For black veterans, these data are in accord with linear dose responses observed between CPAP use and FOSQ scores described in predominantly white samples.[19,20]

Interestingly, the functional status domains with significant findings (social and intimacy) involve interpersonal relationships (friends, family, and significant others) as opposed to general productivity, activity level, and vigilance. In blacks with higher CPAP adherence, improvements in EDS may have a greater impact on social activities and sexual function than the effects reported in whites/Hispanics with similar CPAP use. One potential explanation for these findings in social function could be related to a greater sense of collectivism (social cohesion and prioritizing group over individual goals) in blacks compared to whites/Hispanics.[40] Thus, the importance of social functions in the black community (e.g., attending church, family gatherings) may have increased the likelihood that black veterans perceived improvements in social function with CPAP therapy.[40] Also, cultural differences in the importance placed upon individual functional outcome domains may partially explain these findings.

The absence of a significant relationship between CPAP daily use and functional status among whites/Hispanics may be related to differences between our sample and those of previous cohorts. The studies of Weaver et al. and Antic et al. excluded patients with comorbid sleep disorders (e.g., insomnia), sedative-hypnotic use, and psychiatric disorders.[19,20] However, our sample included patients with comorbid insomnia and psychiatric comorbidities, factors which were included as part of several covariates. Although we adjusted for psychiatric diagnoses, we did not adjust for *active* psychiatric symptoms, which may have influenced FOSQ scores in patients despite adherence to CPAP. Furthermore, we cannot exclude that the positive relationship between CPAP use and FOSQ scores observed for blacks was the result of lower follow-up rates among those experiencing little benefit from CPAP therapy. This hypothesis is supported by the significantly shorter length of CPAP ownership observed in blacks compared to whites/Hispanics (**Table 2**). At our center, blacks are less likely to return for CPAP adherence visits in the first year after initial CPAP distribution in comparison to whites/Hispanics.[42] In longitudinal studies providing CPAP at no cost to participants, lower follow-up rates for blacks have also been noted.[25] These race-ethnic differences in clinical follow-up may have contributed to the observed race-ethnic differences in functional outcomes of sleep if white/Hispanic veterans with impaired functional outcomes returned to our clinic while black veterans with low FOSQ scores failed to do so. Further research concerning race-ethnic differences in follow up in OSAS clinics is still needed.

Limitations

Our study has several limitations beyond those previously mentioned. One major limitation is the retrospective, cross-sectional design which precludes determining if the race-ethnic differences in functional outcomes of sleep observed were present prior to CPAP initiation or were the result of differential treatment adherence. As our assessments occurred only after treatment was initiated, our data cannot examine how functional outcomes changed over time but consists only of post-treatment comparisons. Also, since the design of this study is cross-sectional, directionality of the associations cannot be determined. Other limitations include not measuring additional variables potentially impacting functional outcomes of sleep and CPAP adherence, including comprehensive socioeconomic status, insufficient sleep duration, sleep quality, or social support.[17,31,43,44] Also, as whites report greater sleep complaints than blacks, reporting bias may have also contributed to our FOSQ findings.[6,17] Finally, our South Florida veteran sample is not representative of the US population with OSAS. We have previously reported that Hispanic veterans at our sleep center are primarily of Cuban and Puerto Rican descent, not Mexican (who are the predominant Hispanic subgroup in the US).[12] However, a recent epidemiological analysis showed that adjusted prevalence of sleep disturbances in Florida (16.4%) to be similar to Northern (16.2%) and Midwestern states (16.1%).[45] In sum, these study characteristics should be considered when generalizing our findings.

Veterans' health-related QOL has been found to be worse than that of civilians in the same race-ethnic group and differs among veterans of varying race-ethnicity.[30,31] Similar race-ethnic comparisons are still lacking for functional outcomes of sleep in veterans with OSAS. Our data show that many veterans with OSAS returning to a CPAP adherence clinic have impaired functional status and that the relationship between CPAP use and functional outcomes may be conditional upon race-ethnicity. These data raise several interesting questions. What other determinants (e.g., neighborhoods, pre-treatment social support) contribute to functional outcomes of sleep in minority samples with OSAS? How do cultural norms about sleepiness contribute to an individual's perceived functional status? Do changes in functional outcomes of sleep with CPAP therapy vary by race-ethnicity? To adequately answer these questions, longitudinal studies of diverse patients with OSAS are needed to determine the influence of race-ethnicity on CPAP use and functional outcomes of sleep.

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