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SCIENTIFIC INVESTIGATIONS

The Effect of Sleeping Environment and Sleeping Location Change on Positive Airway Pressure Adherence

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Study Objectives: Poor adherence undermines the effectiveness of positive airway pressure (PAP) therapy for sleep apnea. Disparities exist in PAP adherence by race/ethnicity and neighborhood socioeconomic status (SES), but the etiology of these differences is poorly understood. We investigated whether home environmental factors contribute to PAP adherence and whether identified factors explain disparities in adherence by SES.
Methods: Adult patients with sleep apnea were surveyed at clinic visits about their sleep environment. Medical records were abstracted for demographic data, sleep apnea severity, comorbidities, and objective PAP adherence. We evaluated the association between aspects of home sleep environment with PAP adherence using multivariate linear and logistic regression, and assessed effect modification by SES factors.
Results: Participants (n = 119) were diverse, with 44% nonwhite and 35% uninsured/Medicaid. After adjusting for age, sex, race/ethnicity, insurance, neighborhood SES, education, and marital status, participants who endorsed changing sleeping location once per month or more (18%, n = 21) had 77% lower odds of meeting PAP adherence criteria (> 4 h/night for 70% of nights) and less PAP use (median −11 d/mo, 95% confidence intervals −15.3, −6.5). Frequency of sleeping location change was the only environmental factor surveyed associated with PAP adherence.
Conclusions: Frequent change in sleeping location is associated with reduced PAP adherence, independent of sociodemographic factors. This novel finding has implications for physician-patient dialogue. PAP portability considerations in device selection and design may modify adherence and potentially improve treatment outcomes. Prospective investigation is needed to confirm this finding and inform design of possible interventions.
Keywords: CPAP, environment, housing, OSA, positive airway pressure, sleep apnea, socioeconomic status, treatment adherence
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BRIEF SUMMARY
Current Knowledge/Study Rationale: Poor adherence undermines the effectiveness of positive airway pressure (PAP) therapy for sleep apnea, and has been associated with factors such as race/ethnicity and neighborhood socioeconomic status (SES). This study investigated home environmental factors as potential barriers to PAP adherence and explored whether they differed by SES.
Study Impact: Frequency of change in sleeping location, independent of SES, was found to be associated with PAP adherence. This novel finding has implications for treatment outcomes and physician-patient dialogue.

INTRODUCTION

Obstructive sleep apnea (OSA) negatively affects daytime alertness and productivity. More than 26% of American adults between the ages of 30 and 70 years have OSA, and its prevalence has been increasing substantially over the past few decades.[1] In addition, OSA has been linked to hypertension, diabetes, and cardiovascular morbidity and mortality, motor vehicle and industrial accidents, and increased medical costs.[2] Currently, the most effective form of therapy for OSA is positive airway pressure (PAP), which has been shown to improve quality of life, reduce daytime sleepiness, and may reduce cardiovascular disease risk among adherent users.[3–7]

However, poor patient adherence undermines the efficacy of symptomatic relief and numerous health benefits of PAP.[8] The determinants of PAP acceptance and adherence are certainly multifactorial, and dozens of individual contributing factors have been studied and examined through the biopsychosocial model.[9,10] In particular, decreased PAP adherence has been associated with demographic factors including sex, age, socioeconomic status (SES), and race/ethnicity.[11,12] Lower duration of PAP use has been observed in black patients when compared with nonblack patients in the United States, and in minority groups in other cultures.[13–15] This may be related to psychosocial stressors and sleep habits,[16] as on average, black individuals have shorter sleep duration and poorer sleep quality than nonblack individuals, leading to reduced total window of opportunity for PAP usage. Personal and culturally influenced beliefs about home or neighborhood safety have also been found to affect sleep quality and duration.[17–21]

Furthermore, just as individual perceptions of benefit can substantially affect PAP adherence, neighborhood norms, social cohesion, and support may contribute to PAP use. Lower PAP acceptance and adherence has been independently linked

with SES, which includes educational attainment and income, and observed disparities in PAP adherence by race may be reduced when adjusted for ZIP code SES.[22,23] Analyses using residential census data have also identified potential relationships not only between SES and PAP adherence, but suggest that neighborhood of residence—both as a marker of SES and of local environmental factors—may be independently associated with sleep quality and likelihood of PAP acceptance and adherence.[14,23,24]

Although low SES and neighborhood factors have been associated with reduced adherence to PAP, the etiology of these differences is not well understood. Many studies have identified environmental factors as contributors to poor sleep. Outdoor noise, light, or crowding may have detrimental effects on sleep initiation and duration.[16,25,26] Inconsistent sleeping environments, such as those encountered by individuals who perform shift work, individuals who travel frequently for work, or individuals experiencing homelessness, have also been linked to negative effects on sleep.[27,28] We hypothesized that these same environmental factors associated with poor sleep would be associated with PAP use. We sought to investigate whether features of the living environment are possible barriers to PAP adherence. We postulated that challenging home environmental factors, such as lack of electrical outlet access, or frequent changes in sleeping location, would be associated with reduced PAP usage, and would likely be more prevalent and contributory in populations with lower SES.

METHODS

Participants

Participants were recruited during clinic visits in an urban sleep center located in Seattle, Washington. Eligible participants were patients in whom obstructive or central sleep apnea was diagnosed and in whom PAP therapy had been prescribed. Patients with narcolepsy and those younger than 18 years were excluded. The study was approved by the institutional review board of the University of Washington and participants provided written informed consent. Recruitment and consent were conducted in the patient's language of choice, and all study materials were available in English, Spanish, and Chinese.

Survey Instrument

Based on informal discussions with patients with OSA regarding barriers to PAP adherence, investigators developed a brief nine-item survey focused on home environment issues. Survey items included: accessibility of nearby electrical outlet, type and consistency of sleeping location, bedroom partners, sleep schedule conflicts, and perceived home safety and comfort. Subjective variables were rated on a Likert scale of 1 (never) to 5 (always). Participants also reported their level of educational attainment and had the opportunity to provide optional comments about their experience with PAP and any perceived barriers or motivators for adherence. See the supplemental material for the complete survey. Participants completed the survey on paper or using an investigator-provided tablet computer.

Other Data Collected

Sociodemographic, comorbidity, and sleep data were abstracted from the electronic medical record. Demographic data collected included age, sex, race/ethnicity, marital status, employment status, insurance status, language spoken and ZIP code of residence. Census-level data from the 2014 American Community survey was used to stratify individual five-digit ZIP codes into SES quartiles. Census variables used included median household income and percentage of residents with some college education, above poverty level, employed, and in owner-occupied housing.

We abstracted the following from the electronic medical record:

1. Comorbidities including diabetes, hypertension, coronary heart disease, heart failure, atrial fibrillation, stroke, asthma, depression, anxiety, insomnia, and smoking history from the electronic medical record problem list.
2. Most recent body mass index (BMI) as measured in the clinical setting in kg/m^2.
3. Diagnostic sleep study results from in-laboratory polysomnography or portable level III home sleep apnea test (HSAT) including the apnea-hypopnea index (AHI) using the 4% oxygen desaturation rule for hypopneas (The AASM Manual of Scoring Sleep and Associated Events: Rules, Terminology and Technical Specifications rule 1B[29]), nadir oxygen saturation, and percent time of oxygen saturation < 90%.
4. Baseline Epworth Sleepiness Scale (ESS) score at initial presentation to sleep clinic.
5. PAP adherence, including type of PAP device (continuous, auto-adjusting, or bilevel), average time used per night (total duration in minutes), and number of days used (per month) from PAP device 30-day data downloads at time of study enrollment.

Analysis

To inform our model, we performed bivariate analysis comparing sociodemographic characteristics, comorbidities, sleep apnea severity, and duration since diagnostic study with PAP adherence criteria. We next examined survey responses by adherence, including having access to an outlet, housing type, safety and comfort of sleeping environment, room sharing, frequency of sleeping location change, and schedule conflicts with bed partners. We dichotomized survey responses as follows: never to sometimes (1–3) versus often to always (4–5); never or a few times per year versus monthly or more often. We also examined for differences in survey responses by individual (education level, insurance status) and neighborhood socioeconomic features (ZIP code SES quartile).

We next performed multivariate regression to assess if the home sleeping environment features associated with PAP adherence in bivariate comparisons remained robust after adjustment for confounders. We included demographics (sex, age, race/ethnicity, marital status), SES indicators (ZIP code SES, education level, and insurance status), sleep apnea severity (AHI > 15 events/h), baseline ESS, and comorbidities (obesity, depression, presence of cardiovascular disease and

Table 1—Characteristics of participants enrolled in the survey study (n = 119).

Age (years), mean ± SD	55.1 ± 13.6
Male, % (n)	57.1 (68)
Married, % (n)	37.6 (45)
BMI (kg/m^2), mean ± SD	35.4 ± 8.7
Comorbidities, % (n)	
Hypertension	60.5 (72)
Diabetes	29.7 (35)
Stroke	3.4 (4)
Heart failure	10.9 (13)
Atrial fibrillation	2.5 (3)
Depression	55.5 (66)
Insomnia	19.5 (23)
Anxiety	40.0 (44)
Chronic pain	22.7 (27)
Kidney failure	4.2 (5)
Smoker (current or former)	45 (52)
Race/ethnicity, % (n)	
White non-Hispanic	56.3 (67)
Black non-Hispanic	18.5 (22.0)
Hispanic	7.6 (9)
Asian	7.7 (9)
Unemployed, % (n)	26.1 (31)
Current/former smoker, % (n)	45.7 (54)
Lowest quartile ZIP SES, % (n)	21.4 (25)
Insurance status, % (n)	
Uninsured	2.5 (3)
Medicaid	31.9 (38)
Insurance status, % (n) *continued*	
Medicare, younger than 65 years	14.2 (17)
Medicare, age 65+	20.2 (24)
Private insurance	31.1 (37)
Highest educational attainment, % (n)	
Elementary school	1.7 (2)
High school	22.2 (26)
Some college	32.5 (38)
College degree	23.1 (27)
Graduate degree	20.5 (24)
Baseline sleep traits, median (IQR)	
ESS score at initial visit	11 (6, 15)
Home sleep apnea test, % (n)	17.2 (20)
In-laboratory study, % (n)	82.8 (96)
Split-night PSG, % (n)	21.0 (24)
Apnea-hypopnea index (events/h)*	28.0 (10.3, 47.4)
Nadir O_2 level (%)	83.0 (75–88)
Time with O_2 Sat < 90% (%)	3.0 (0.3, 13.9)
Months from diagnostic sleep study to enrollment	31 (10, 64)
PAP device usage, median (IQR)	
Minutes per night	301 (194, 407)
Days per month	27 (15, 30)
PAP device type, % (n)	
Continuous	34.2 (40)
Autoadjusting	54.7 (64)
Bilevel PAP	9.4 (11)
Adaptive servo-ventilation	1.7 (2)

Demographic, socioeconomic, and sleep characteristics of all study participants (n = 119). * = data included for n = 75 participants; data not included for some participants because the sleep center changed how they scored hypopneas from The AASM Manual of Scoring Sleep and Associated Events: Rules, Terminology and Technical Specifications rule 1A to 1B[28] in 2014. ESS = Epworth Sleepiness Scale, IQR = interquartile range, PAP = positive airway pressure, PSG = polysomnography, O_2 sat = oxygen saturation, SD = standard deviation, SES = socioeconomic status.

diabetes) in the most fully adjusted models. The PAP adherence outcome was evaluated both as a continuous variable in min/d and as a dichotomous variable, using Centers for Medicare and Medicaid Services (CMS) adherence requirements of > 4 h/night PAP use for 70% of nights in 30-day download.[30] We also evaluated the association of frequency of sleep location change with PAP use (d/mo). We used generalized linear modeling and adjusted for confounders identified in bivariate analysis as associated with PAP adherence. As an exploratory analysis, we examined whether sleep location change frequency was associated with the outcome of daily PAP use (30 d/mo compared to < 30 d/mo).

We then built models using both forward and backward stepwise multivariate regression, using both linear and logistic regression for PAP use as continuous and dichotomous outcomes, respectively, in the model building. We began with all covariates of interest: survey responses, sociodemographics, and comorbidities as detailed earlier, retaining those variables with a significance of $P < .15$.

Finally, we evaluated whether SES modified the association of home environmental features with PAP adherence, using stratified analyses of adherence based on race/ethnicity, education level, insurance status, and ZIP code SES quartile.

RESULTS

During the 2 months of enrollment in July 2015 to August 2015, 170 eligible participants were approached. Data abstraction from the medical record was performed sequentially on the first 119 of 153 participants who provided consent and completed the survey. The 34 remaining participants were excluded because of incomplete data abstraction.

Of the 119 participants, 57% were male (n = 68), the mean age was 55 ± 13.6 years, and mean BMI was 35.4 ± 8.7 kg/m^2, (**Table 1**). Participants were diverse with 44% nonwhite or Hispanic (n = 51). Most had Medicare or Medicaid insurance, whereas 31% had private insurance (n = 37). Approximately 44% had a college degree or higher level of education (n = 51). Participants typically had moderate to severe sleep apnea, with a median AHI of 28 events/h, baseline ESS score of 11, and nadir oxygen saturation of 83%. Most had continuous positive

Table 2—Home environment survey results.

	Adherent	Nonadherent
All participants (n = 119), % (n)	49 (58)	51 (61)
PAP use, median (IQR)		
Minutes per night	409 (348, 465)	185.5 (19, 262)
Days per month	30 (28, 30)	15 (2, 24)
Endorsed home environment features, % (n)		
No easily available outlet (n = 9) *	22 (2)	78 (7)
No bedroom (n = 15)	53 (8)	47 (7)
Not living in a house or apartment (n = 13)	62 (8)	38 (5)
Changing sleeping location ≥ 1×/mo (n = 21) †	29 (6)	71 (15)
Conflicting schedule bed partner (n = 32)	47 (15)	53 (17)
Consider sleeping space sometimes/often/always, % (n)		
Unsafe (n = 5)	20 (1)	80 (4)
Noisy (n = 24)	50 (12)	50 (12)
Temperature uncomfortable (n = 29)	48 (14)	52 (15)
Not dark (n = 25)	52 (13)	48 (12)

Overall total number of participants endorsing each environmental feature, categorized by percent meeting PAP adherence. Participants who reported living in a place that was neither a house nor apartment included those who were homeless and living in shelters, vehicles, or mobile homes. Symbols indicate statistical significance: * = $P < .10$, † = $P < .05$. IQR = interquartile range, PAP = positive airway pressure.

airway pressure (CPAP) devices (89%, n = 95), both autoadjusting and fixed pressure, for OSA; 11% had various bilevel PAP modalities (fixed bilevel PAP or adaptive servoventilation). These characteristics were compared with the center's overall patient population and found to be representative. Only 10% of participants were "novel" PAP users in whom sleep apnea had been diagnosed within 3 months of study enrollment. There was a median interval of 31 months (interquartile range [IQR] 10, 64) between the diagnostic sleep study and study enrollment.

Almost half of the participants met CMS adherence criteria on their most recent download (49%, n = 58). Participants utilized PAP a median of 27 d/mo (IQR 15, 30) and 5 h/night, median of 301 minutes (IQR 194, 407), **Table 1**. Approximately 11% of participants (n = 13) had no PAP use on their 30-day download. Participants who were adherent to PAP therapy differed from nonadherent participants by race and education level in bivariate comparisons but not by other SES metrics (insurance status or residential SES ZIP code quartiles), comorbidities, sleepiness, or sleep apnea severity.

Forty percent of participants (n = 48) reported that they did not always feel safe and comfortable in their sleeping environment. These participants had similar adherence rates to those reporting always feeling safe and comfortable in their sleeping environments. Nine participants had issues plugging in their PAP device and five shared a bedroom with a child (**Table 2**). Both of these groups had lower adherence (22% and zero, respectively), but with few participants in these categories, neither variable was statistically significant. Participants reporting a different sleep schedule than their bed partner had similar adherence as those with a compatible schedule. There was no difference in adherence by home type (house, apartment, assisted living, or homeless) or sleeping location (bedroom, living room, or other).

There were differences in survey responses by insurance status, with those on Medicaid more often reporting lack of bedroom, more noise and temperature discomfort, and not always feeling safe in their sleeping space. Similarly, those without a college degree reported more noise and temperature discomfort in their sleeping space. These sleeping environment traits did not differ by race/ethnicity or ZIP code SES quartile.

Participants who changed their sleeping location 1×/mo or more (n = 21) were significantly less adherent than those who rarely changed sleeping location (less than 1×/mo). After adjusting for demographics, comorbidities and sleep apnea severity, changing sleeping location ≥ 1×/mo was associated with 77% lower odds of reaching CMS adherence (**Table 3**, model 2) compared to rarely changed sleeping location. Once a month or more frequent change in sleeping location was also associated with less PAP use (median −11 d/mo, 95% confidence interval [CI] −6.5, −15.3 [**Table 4**, model 2] average −87 min/night, 95% CI 6, 168 [**Table 5**, model 1]) compared to those who rarely changed sleeping location. In models also including sleep apnea severity and comorbidities, the effect of frequent sleep location change was more substantial. In exploratory analysis, we also found that participants who changed sleeping location ≥ 1×/mo had 87% lower odds of being daily PAP users and fourfold greater odds of no PAP use (data not shown).

There was evidence of effect modification on the association of sleeping location change and adherence by race and education, but not by insurance type or ZIP code SES quartile. All participants who reported high school education or less were nonadherent if they changed sleeping location ≥ 1×/mo, compared to 60% of those with higher than high school education. Similarly, 100% of those belonging to a racial/ethnic minority group and reporting frequent sleeping location change were non-adherent to PAP, whereas 53% of white individuals were nonadherent with the same frequency of sleeping location

Table 3—Association between educational attainment and sleeping location change frequency with PAP adherence.

Predictor	Model 1 (n = 97)	Model 2 (n = 96)	Model 3 (n = 109)
Education (ref high school or less)			
Some college/associate's degree	4.7 (1.0, 23.2)	3.44 (0.64, 18.6)	3.0 (0.8, 10.5)
College degree/graduate degree *	18.7 (2.7, 130.9)	13.9 (2.1, 91.5)	6.4 (1.7, 24.5)
Sleeping location change ≥ 1×/mo *	0.20 (0.05, 0.88)	0.23 (0.05, 1.02)	0.22 (0.07, 0.75)

Values presented as odds ratios (95% confidence interval). Adherence is defined as PAP use for ≥ 4 h/night for ≥ 70% days in a 30-day period. Odds ratios computed using multivariate logistic regression. Having a college degree or higher level of education is associated with increased PAP adherence. Changing sleeping location once per month or more is associated with decreased PAP adherence. Asterisk indicates statistical significance: * = $P < .05$. Model 1 adjusted for sex, age, obesity, baseline sleepiness (Epworth Sleepiness Scale score), obstructive sleep apnea severity (apnea-hypopnea index > 15 events/h), race/ethnicity, insurance, ZIP code socioeconomic status, and marital status. Model 2 included adjustments as in model 1 plus diabetes mellitus, cardiovascular disease, and depression. Model 3 (from stepwise regression) adjusted for race/ethnicity, marital status, and obesity. PAP = positive airway pressure.

Table 4—Association between sleeping location change frequency and median days per month of PAP use using multivariate linear regression.

Predictor	Model 1 (n = 110)	Model 2 (n = 106)	Model 3 (n = 105)
Sleeping location change ≥ 1x/mo	−8.1 (−12,3, −3.9)	−10.9 (−15.3, −6.5)	−9.0 (−13.3, −4.6)

Values presented as β (95% confidence interval). Changing sleeping location once per month or more is associated with decreased median PAP use in days per month. $P < .05$ for all. Model 1 unadjusted using generalized linear modeling. Model 2 included adjustment for age, marital status, education level, and depression. Model 3 adjusted for race, insurance status, education level, ZIP code socioeconomic status. PAP = positive airway pressure.

Table 5—Association of frequent sleeping location change with average PAP use in minutes per night, using multivariate linear regression.

Predictor	Model 1 (n = 110)	Model 2 (n = 100)	Model 3 (n = 113)
Sleeping location change ≥ 1x/mo	−87.0 (−168.0, −5.9)	−115.1 (−207.8, −23.0)	−89.2 (−163.5, −14.9)

Values presented as β (95% confidence interval). Changing sleeping location once per month or more is associated with decreased average PAP use in minutes per night. $P < .05$ for all. Model 1 adjusted for age, sex, marital status, race, ethnicity, education level, insurance status, and socioeconomic status ZIP code. Model 2 included adjustments for depression, cardiovascular disease, obesity, baseline sleepiness, and apnea-hypopnea index > 15 events/h. Model 3 (from stepwise regression) adjusts for depression, marital status, diabetes, and race/ethnicity. PAP = positive airway pressure.

change. Effect modification findings were similar for the outcome of daily PAP use.

Education level was also independently associated with PAP adherence, even after adjustment for sociodemographics, sleep apnea severity, and comorbidities. Those with a high school education or less had 83% lower odds of PAP adherence. Those with a college degree or more were 14 times more likely (95% CI 2.1, 91.5) to be adherent than those with a high school degree or less (**Table 3**). Racial/ethnic minority status, insurance type, and ZIP code SES quartile were not associated with adherence in adjusted models.

DISCUSSION

This survey study of participants on PAP therapy identifies a novel association between frequency of change in sleeping location and PAP adherence. Participants who changed sleeping location ≥ 1×/mo (almost 20% of our sample) had lower rates of adherence and utilized PAP therapy for fewer d/mo and fewer h/night. This relationship was independent of demographic factors, comorbidities, and sleep apnea severity, and not modified by insurance status or ZIP code SES. However, the effect of more frequent change in sleeping location was more profound in racial/ethnic minorities and those with a high school education or less. Other environmental factors that could influence sleeping opportunity and comfort, such as crowding, perceived safety, or noise in the sleeping environment, which did differ by insurance status and education level, were not associated with PAP adherence. However, it should be noted that those completing the survey had accepted PAP therapy and were enrolled a median of 31 months after their diagnostic sleep study. Distinct neighborhood and home factors may influence overall PAP acceptance, initial adherence, and willingness to return to a sleep clinic.

Of the sociodemographic factors examined in our study, only education level was independently associated with PAP adherence. Community-level factors, race/ethnicity and insurance status were not found to be associated with PAP adherence as has been observed in other studies.[11,14,15] Racial/ethnic minorities had lower adherence but this association did not persist after adjustment for education level. ZIP code SES based on United States census data was used as a proxy for housing quality and neighborhood SES, and was not associated with PAP adherence as demonstrated in prior studies.[14,23] Given the rapidly gentrifying and often densely populated neighborhoods in the region of our study, ZIP code is likely too crude to characterize the true neighborhood SES. More precise

geo-coded data such as census-tract would be better able to assess the association with neighborhood.

Our findings suggest factors contributing to PAP adherence may be similar to other treatment modalities requiring significant patient participation and favorable home environment. Housing stability has been found to affect patient adherence and treatment outcomes in numerous chronic conditions, such as insulin pumps in patients with diabetes and corticosteroid inhalers in patients with asthma.[31,32] Similar findings have also been reported in studies of adherence to long-term maintenance treatments including antiretroviral regimens in patients with HIV and opioid replacement for patients with substance use disorders.[33,34]

Furthermore, although most work in this area has focused on patients in the lowest socioeconomic strata, the findings from our study indicate that changing sleeping location negatively affects PAP adherence even among those in higher SES strata. This is supported by qualitative information obtained from participants in the optional comments section at the end of our survey, with a subset of representative comments presented in the supplemental material. Many who frequently changed sleeping location provided details about their living situation—these ranged from homelessness and frequent "couch-surfing" with friends, to spending the night a few times a week with a romantic partner, to business travelers living primarily out of hotels and those who maintain a waterfront vacation home. Thus, changing sleeping location, regardless of reason, may reduce PAP usage. This may be a consequence of the bulky, cumbersome nature of PAP therapy and its lack of easy transportability. The effects were most pronounced among those with less education and racial/ethnic minority status, possibly due to greater baseline life stressors or resource limitations adding to the burden of PAP mobilization.

These findings have potential utility for clinicians and may inform physician-patient conversations. For example, patients with frequent sleeping location changes may benefit from obtaining a smaller, travel-friendly PAP device or battery pack, or using a backup treatment modality such as a mandibular advancement device. This reinforces the importance of reminding patients to bring their PAP devices when on the move, and proactively addressing challenges that may occur with air travel or time spent in areas with differing voltage or access to electricity.[35] Variability in the sleep environment may affect PAP usage even among motivated patients, and may play a role in shaping which patients become PAP "attempters" versus those who consistently adhere to treatment.[36] It is also crucial for physicians to recognize that there is currently little to no insurance coverage for many of these potential strategies, and the issues we have identified likely disproportionately affect and will be harder to overcome for patients with lower SES.

This observational study of PAP adherence was also conducted after implementation of the Affordable Care Act in the United States. Nearly one-third of the study population was newly enrolled in Medicaid (Washington Apple Health) as a result of expanded Medicaid eligibility in Washington state, and were likely previously unable to obtain PAP devices. Despite having incomes below 138% of the federal poverty line ($16,243 annual income for an individual or $33,465 for a family of four)[37] during the year of the study, these participants did not have poorer adherence than higher-income peers with private insurance. Most studies looking at PAP treatment and SES have focused on the differences between insured and uninsured populations, so it is possible that access to affordable insurance coverage and regular health maintenance could help to attenuate some of the previously observed differences in adherence associated with lower SES status.

Our pilot study has several important limitations that should be considered. First, our sample of 119 participants has limited power, especially to detect differences in the more rarely endorsed sleep environment features and among sociodemographic subsets. Our convenience sample was drawn from a single academically affiliated urban center that may not be generalizable to all sleep centers and populations. As a cross-sectional observational study based on a newly developed survey, there may be other factors that affect adherence that were unmeasured, and our survey has not yet been validated. Comorbidities were abstracted from the electronic medical record and may be inaccurate or incomplete. Sample bias may account for higher observed adherence levels, as patients who were nonadherent may be less likely to return to the clinic and therefore less likely to be enrolled in the study—though it is worth noting that PAP adherence in our participants was 49%, which is consistent with the lower end of most population-level adherence rates[8] as well as the clinic's overall patient population.

Similarly, our study was limited by using insurance status as a proxy for income, with Medicaid status as a marker of low income. Many of our participants on Medicaid were highly educated and young. This may have resulted in a mismatch among individual-level SES markers as participants potentially had access to resources through friends and family members with higher SES, blunting potential differences between privately insured and Medicaid groups. However, this study does benefit from a racially diverse population (44% minorities), with objective measures of PAP adherence and three distinct measures of SES, allowing us to distinguish effects of education from other SES markers.

In conclusion, this study demonstrates a strong association between sleeping location change frequency and PAP adherence. Our findings support the importance of discussing lifestyle and sleeping environment both at initial PAP consultation and ongoing follow-up. This may allow providers to identify modifiable barriers to adherence, develop more specific, patient-centered solutions, and advocate on behalf of patients around issues such as insurance coverage or housing access. Portability considerations could also be incorporated into device design and user teaching protocols. Improving PAP mobility may modify nonadherence behaviors and could potentially affect sleep apnea treatment outcomes. Prospective investigation is still needed to confirm these findings and inform potential interventions.

ABBREVIATIONS

AHI, apnea-hypopnea index
CPAP, continuous positive airway pressure

CMS, Centers for Medicare and Medicaid Services
ESS, Epworth Sleepiness Scale
HSAT, home sleep apnea test
OSA, obstructive sleep apnea
PAP, positive airway pressure
SES, socioeconomic status

REFERENCES

1. Peppard PE, Young T, Barnet JH, Palta M, Hagen EW, Hla KM. Increased prevalence of sleep-disordered breathing in adults. *Am J Epidemiol*. 2013;177(9):1006–1014.
2. Kapur VK. Obstructive sleep apnea: diagnosis, epidemiology, and economics. *Respir Care*. 2010;55(9):1155–1167.
3. Weaver TE, Maislin G, Dinges DF, et al. Relationship between hours of CPAP use and achieving normal levels of sleepiness and daily functioning. *Sleep*. 2007;30(6):711–719.
4. Campos-Rodriguez F, Queipo-Corona C, Carmona-Bernal C, et al. Continuous positive airway pressure improves quality of life in women with obstructive sleep apnea. A randomized controlled trial. *Am J Respir Crit Care Med*. 2016;194(10):1286–1294.
5. Marin JM, Carrizo SJ, Vicente E, Agusti AG. Long-term cardiovascular outcomes in men with obstructive sleep apnoea-hypopnoea with or without treatment with continuous positive airway pressure: an observational study. *Lancet*. 2005;365(9464):1046–1053.
6. Martinez-Garcia MA, Soler-Cataluna JJ, Ejarque-Martinez L, et al. Continuous positive airway pressure treatment reduces mortality in patients with ischemic stroke and obstructive sleep apnea: a 5-year follow-up study. *Am J Respir Crit Care Med*. 2009;180(1):36–41.
7. Walia HK, Thompson NR, Katzan I, Foldvary-Schaefer N, Moul DE, Mehra R. Impact of sleep-disordered breathing treatment on quality of life measures in a large clinic-based cohort. *J Clin Sleep Med*. 2017;13(11):1255–1263.
8. Weaver TE, Grunstein RR. Adherence to continuous positive airway pressure therapy: the challenge to effective treatment. *Proc Am Thorac Soc*. 2008;5(2):173–178.
9. Shapiro GK, Shapiro CM. Factors that influence CPAP adherence: an overview. *Sleep Breath*. 2010;14(4):323–335.
10. Crawford MR, Espie CA, Bartlett DJ, Grunstein RR. Integrating psychology and medicine in CPAP adherence--new concepts? *Sleep Med Rev*. 2014;18(2):123–139.
11. Joo MJ, Herdegen JJ. Sleep apnea in an urban public hospital: assessment of severity and treatment adherence. *J Clin Sleep Med*. 2007;3(3):285–288.
12. Sawyer AM, Gooneratne NS, Marcus CL, Ofer D, Richards KC, Weaver TE. A systematic review of CPAP adherence across age groups: clinical and empiric insights for developing CPAP adherence interventions. *Sleep Med Rev*. 2011;15(6):343–356.
13. Bakker JP, O'Keeffe KM, Neill AM, Campbell AJ. Ethnic disparities in CPAP adherence in New Zealand: effects of socioeconomic status, health literacy and self-efficacy. *Sleep*. 2011;34(11):1595–1603.
14. Billings ME, Auckley D, Benca R, et al. Race and residential socioeconomics as predictors of CPAP adherence. *Sleep*. 2011;34(12):1653–1658.
15. Wallace DM, Shafazand S, Aloia MS, Wohlgemuth WK. The association of age, insomnia, and self-efficacy with continuous positive airway pressure adherence in black, white, and Hispanic U.S. Veterans. *J Clin Sleep Med*. 2013;9(9):885–895.
16. Wallace DM, Williams NJ, Sawyer AM, et al. Adherence to positive airway pressure treatment among minority populations in the US: a scoping review. *Sleep Med Rev*. 2018;38:56-69.
17. Simonelli G, Dudley KA, Weng J, et al. Neighborhood factors as predictors of poor sleep in the Sueno Ancillary Study of the Hispanic Community Health Study/Study of Latinos. *Sleep*. 2017;40(1).
18. Johnson DA, Simonelli G, Moore K, et al. The neighborhood social environment and objective measures of sleep in the Multi-Ethnic Study of Atherosclerosis. *Sleep*. 2017;40(1).
19. Simonelli G, Patel SR, Rodríguez-Espínola S, et al. The impact of home safety on sleep in a Latin American country. *Sleep Health*. 2015;1(2):98–103.
20. Billings ME, Rosen CL, Wang R, et al. Is the relationship between race and continuous positive airway pressure adherence mediated by sleep duration? *Sleep*. 2013;36(2):221–227.
21. Hale L, Hill TD, Friedman E, et al. Perceived neighborhood quality, sleep quality, and health status: evidence from the Survey of the Health of Wisconsin. *Soc Sci Med*. 2013;79:16–22.
22. Simon-Tuval T, Reuveni H, Greenberg-Dotan S, Oksenberg A, Tal A, Tarasiuk A. Low socioeconomic status is a risk factor for CPAP acceptance among adult OSAS patients requiring treatment. *Sleep*. 2009;32(4):545–552.
23. Platt AB, Field SH, Asch DA, et al. Neighborhood of residence is associated with daily adherence to CPAP therapy. *Sleep*. 2009;32(6):799–806.
24. Kendzerska T, Gershon AS, Tomlinson G, Leung RS. The effect of patient neighbourhood income level on the purchase of continuous positive airway pressure treatment among sleep apnea patients. *Ann Am Thorac Soc*. 2016;13(1):93–100.
25. Muzet A. Environmental noise, sleep and health. *Sleep Med Rev*. 2007;11(2):135–142.
26. Ohayon MM, Milesi C. Artificial outdoor nighttime lights associate with altered sleep behavior in the American general population. *Sleep*. 2016;39(6):1311–1320.
27. Jay SM, Aisbett B, Sprajcer M, Ferguson SA. Sleeping at work: not all about location, location, location. *Sleep Med Rev*. 2015;19:59–66.
28. Chang HL, Fisher FD, Reitzel LR, Kendzor DE, Nguyen MA, Businelle MS. Subjective sleep inadequacy and self-rated health among homeless adults. *Am J Health Behav*. 2015;39(1):14–21.
29. Berry RB, Brooks R, Gamaldo CE, et al.; for the American Academy of Sleep Medicine. *The AASM Manual of Scoring Sleep and Associated Events: Rules, Terminology and Technical Specifications*. Version 2.0. Darien, IL: American Academy of Sleep Medicine; 2012.
30. Centers for Medicare and Medicaid Services. Positive Airway Pressure (PAP) Devices: Complying with Documentation & Coverage Requirements. https://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNProducts/downloads/PAP_DocCvg_Factsheet_ICN905064.pdf. Published October 2016. Accessed March 7, 2018.
31. Keene DE, Guo M, Murillo S. "That wasn't really a place to worry about diabetes": Housing access and diabetes self-management among low-income adults. *Soc Sci Med*. 2018;197:71–77.
32. Buu MC, Carter L, Bruce JS, Baca EA, Greenberg B, Chamberlain LJ. Asthma, tobacco smoke and the indoor environment: a qualitative study of sheltered homeless families. *J Asthma*. 2014;51(2):142–148.
33. Aidala AA, Wilson MG, Shubert V, et al. Housing status, medical care, and health outcomes among people living with HIV/AIDS: a systematic review. Am *J Public Health*. 2016;106(1):e1–e23.
34. Buchholz JR, Malte CA, Calsyn DA, et al. Associations of housing status with substance abuse treatment and service use outcomes among veterans. *Psychiatr Serv*. 2010;61(7):698–706.
35. Bodington R, Johnson O, Carveth-Johnson P, Faruqi S. Travel with CPAP machines: how frequent and what are the problems? *J Travel Med*. 2018;25(1).
36. Wohlgemuth WK, Chirinos DA, Domingo S, Wallace DM. Attempters, adherers, and non-adherers: latent profile analysis of CPAP use with correlates. *Sleep Med*. 2015;16(3):336–342.
37. Department of Health and Human Services. Annual Update of the HHS Poverty Guidelines. https://www.federalregister.gov/documents/2015/01/22/2015-01120/annual-update-of-the-hhs-poverty-guidelines. Published January 22, 2015. Accessed March 7, 2018.

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