Predictors of continuous positive airway pressure use during the first week of treatment

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SUMMARY

This study aimed to identify pre-treatment and immediate early treatment factors predicting continuous positive airway pressure (CPAP) use during the first week of therapy, when the pattern of non-adherence is established. Four domains of potential predictors were examined: pre-treatment demographic and clinical factors, patients' perceived self-efficacy, treatment delivery (mask leak and bothering side effects) and immediate disease reduction (residual respiratory events and flow limitation). The Autoset™ Clinical System objectively documented daily CPAP use, mask leak, residual respiratory events and flow limitation. Ninety-one CPAP-naive patients with newly diagnosed obstructive sleep apnea were followed for 1 week after treatment initiation. Mean CPAP daily use during the first week was 3.4 ± 2.7 h, with significantly lower use observed in black than non-black participants (2.7 versus 4.4 h, respectively, $P = 0.002$). Less intimacy with partners caused by CPAP was the only treatment side effect correlated with CPAP use ($r = -0.300$, $P = 0.025$). Reduced CPAP use during the first week was associated simultaneously with being black, higher residual apnea–hypopnea index and the treatment side effect of less intimacy with partners. The three factors together accounted for 25.4% of the variance in the CPAP use ($R^2 = 0.254$, $P < 0.01$). These data suggest the need to assess the impact of CPAP on intimacy and troubleshooting aspects of the treatment that interfere with sexual relationships. Assessing the presence of residual respiratory events may be important in promoting CPAP adherence. The association of race and CPAP use needs to be explored further by including more socioeconomic information.

INTRODUCTION

Obstructive sleep apnea (OSA) affects at least 4% of men and 2% of women in the middle-aged population (Young *et al.*, 1993). Untreated OSA adds at least 3.4 billion dollars to annual medical costs in the United States (Kapur *et al.*, 1999) and has negative health consequences, such as excessive daytime sleepiness (Gottlieb *et al.*, 1999), diminished quality of life (Baldwin *et al.*, 2001), hypertension (O'Connor *et al.*, 2009; Peppard, 2009), ischemic stroke (Redline *et al.*, 2010) and increased all-cause mortality (Marshall *et al.*, 2008). Effective treatment for OSA can be achieved through the use of CPAP, which is the primary and most effective treatment option for OSA (Mcdaid *et al.*, 2009). However, treatment success depends on CPAP adherence, which is highly variable (Aloia *et al.*, 2008; Weaver and Grunstein, 2008).With increasingly robust evidence for the benefits of CPAP, poor adherence to CPAP remains the greatest impediment to effective treatment for OSA (Weaver and Sawyer, 2010).

The development of ways to improve CPAP use depends heavily upon first establishing reliable predictors of CPAP non-adherence. Evidence indicates that the CPAP non-adherence pattern is established early in treatment, within the first week of therapy (Budhiraja *et al.*, 2007; Weaver *et al.*, 1997a), and that a dramatic decline of CPAP use in the first few days predicts long-term use (Aloia *et al.*, 2007; Budhiraja *et al.*, 2007; Kribbs *et al.*, 1993). Given how early non-adherence to CPAP occurs, the purpose of this study was to identify salient pre-treatment and immediate early treatment factors that predict CPAP use during the first week of treatment. Although numerous studies have examined factors influencing CPAP use, few reliable determinants have been identified consistently, especially during the most vulnerable period—the first treatment week. Previous studies have largely ignored factors associated with patients' self-efficacy, and aspects of CPAP delivery and immediate disease reduction when used by the patients in the home.

Using a prospective design, four domains of factors were examined: (i) pre-treatment demographic and clinical factors [e.g. race, age, apnea–hypopnea index (AHI), daytime sleepiness, functional status and neurobehavioral function]; (ii) patients' perceptions of self-efficacy, which reflect patients' perceptions of their risks relative to OSA, their expectations regarding CPAP use behaviors that can affect those risks and their beliefs in their ability to master the demands of CPAP therapy by means of adaptive action; (iii) treatment delivery as practiced by patients at home, which refers to how they administer CPAP (e.g. mask leak) and its bothering side effects; and (iv) immediate disease reduction when CPAP therapy is used by the patient at home (e.g. residual AHI and flow limitation). We predicted that multiple pre-treatment and immediate early treatment factors would predict CPAP use during the first week of treatment. The generation of such a predictive model would enable pretreatment prediction of those likely to have difficulty with CPAP use, and serve as the basis for the development of maximally effective interventions in order to enhance CPAP use by patients with OSA.

METHODS

Participants

Participants were recruited consecutively from the Penn Center for Sleep Disorders at the University of Pennsylvania Health System. Patients (age > 18 years) with newly diagnosed OSA and prescribed CPAP treatment were eligible for recruitment. Patients who had a history of blindness or a reading level below the fifth grade were excluded. All eligible patients were approached to participate in the study. The study was approved by the University of Pennsylvania Institutional Review Board, and all participants provided written informed consent.

The Autoset™ Clinical System (AutoSet™; ResMed Corp., San Diego, CA, USA), a computer-controlled CPAP machine, served as the treatment delivery device, and documented the immediate treatment efficacy and daily CPAP use in this study. The participants' CPAP machine was set to manual mode at the prescribed pressure and the device was connected to an external portable computer containing the Autoset clinical software and associated programs. This arrangement enabled the collection of both raw and summary data. Only summary data retrieved from the Autoset™ Clinical System are used in this study. The devices (CPAP machine connected to external computer) and Mirage mask were delivered by one home health-care company to patients whose insurance covered CPAP treatment, according to routine management.

Procedure

On the evening of their scheduled polysomnography (PSG), participants provided information regarding demographic characteristics, and completed measurements including daytime sleepiness, functional status and perceived self-efficacy, followed by the evaluation of neurobehavioral performance. The split-night PSG study, during which the diagnosis of OSA was made in the first half of the night followed by a CPAP pressure titration during the second half of the night, was conducted according to the usual procedures in the sleep center in keeping with the guidelines established by the American Sleep Disorders Association (1997). The following PSG signals were recorded: electroencephalograms (C3M2, C4M1, O2M1), bilateral electroculograms, electromyograms of the chin muscles and right and left anterior tibialis, electrocardiogram (lead 1), movement of the rib cage and abdomen (piezoelectric crystal), arterial oxygen saturation by a finger oximeter, nasal airflow recorded using nasal thermisters and body position. The AHI was computed from the number of obstructive apneas and hypopneas according to the American Academy of Sleep Medicine criteria (1999). On the scheduled first day of treatment, the AutoSet™ device was connected to the external computer and delivered to the participant's home by the durable medical equipment company providing service to the participant. The AutoSet™ was programmed via manual mode by the sleep center technician to deliver a constant CPAP pressure during home treatment. The device was turned on and off by depressing a button that activated the computer and CPAP device, recording the duration of CPAP use and other key variables. Each participant completed a daily diary documenting side effects of the CPAP treatment during the first week. After the first week of treatment, the self-efficacy questionnaire was again administered to the participants.

Measurements

Subjective sleepiness, functional status and neurobehavioral function

Subjective daytime sleepiness was assessed with the Epworth Sleepiness Scale (ESS) (Johns, 1991). The ESS is an extensively used brief questionnaire with items about the likelihood of falling asleep in eight soporific situations rated on a 0–3 scale, with 0 = would never doze to 3 = high chance of dozing.

Functional status was measured by the Functional Outcomes of Sleep Questionnaire (FOSQ) (Weaver *et al.*, 1997b). The FOSQ is a 30-item self-report, disease-specific measure designed to assess the impact of sleep disorders of excessive sleepiness on multiple activities of daily living. It includes five subscales: activity level, vigilance, intimacy and sexual relationships, general productivity and social outcomes. The potential range for each subscale score is 1–4, with a total score of 5–20. Lower scores on the FOSQ indicate greater functional disability. The FOSQ has established content validity, test–retest reliability (0.90), internal consistency (0.96) and concurrent validity with standardized generic measures of functional status (Weaver *et al.*, 1997b).

Two performance tests were used primarily to indicate neurobehavioral function in this study: the Profile of Mood States (POMS) (Mcnair *et al.*, 1971) and the psychomotor vigilance task (PVT) (Dinges and Powell, 1985). The POMS consists of 65 adjectives on which subjects rate themselves on how they feel 'today' using a 0–4 scale ('not at all' to 'extremely'), including six subscales: tension–anxiety, depression–dejection, anger–hostility, vigor–activity, fatigue–inertia and confusion–bewilderment. The total mood disturbance score from the POMS gives a global estimate of mood state. The PVT evaluates the ability to sustain attention and respond in a timely manner to salient signals presented at random intervals over a 10-min test. The number of lapses of attention (failure to respond in a timely manner with reaction time ≥ 500 ms) from the PVT test is used commonly to indicate the degree of sustained attention under conditions of sleep deprivation and in sleep disorders.

Perceptions of self-efficacy

Self-efficacy was measured by the Self-Efficacy Measure for Sleep Apnea (SEMSA) pre-treatment and after 1 week of CPAP therapy (Weaver *et al.*, 2003). This 26-item measure developed by our team contains three subscales: risk perception of OSA (e.g. 'chances of falling asleep driving'), outcome expectancies of CPAP (e.g. 'job performance will improve') and treatment self-efficacy (e.g. 'I would use CPAP if it makes my nose stuffy'). This scale demonstrated good psychometric properties in validation studies of OSA patients. We have reported Cronbach's alpha as 0.90 for the total scale and 0.85–0.89 for the three subscales, and the test–retested reliabilities ranged from 0.68 to 0.77 (Weaver *et al.*, 2003).

Treatment delivery

Aspects of treatment delivery were indicated by mask leak and treatment side effects as practiced by patients at home. Mask leaks (liters per minute of airflow) were measured continuously throughout CPAP use by the external portable computer, yielding a single cumulative hourly value across the night. Nineteen side effects related to CPAP use were recorded daily by the patients using a diary, such as claustrophobia, dry nose, less intimacy, disturbed sleep, irritated skin and headaches. An index was used to document the presence and severity of each side effect, ranged from 0 (not a problem) to 3 (a serious problem) (Kribbs *et al.*, 1993; Weaver *et al.*, 1997a).

Immediate disease reduction

The Autoset^{TM} system recorded the number of apneic and hypopneic events for the calculation of residual AHI, and the number of episodes and duration of mask leaks during CPAP treatment. Additionally, this device also provided information on the presence of flow-limitation on a breath-by-breath basis. Flow limitation was defined by the AutoSet^{TM} using a curvature index that is a measure of the deviation from unit-scaled flow over the middle 50% of inspiratory time; flow limitation was defined arbitrarily as the percentage of time spent at or below a criterion value of 0.15 deviation. Apneic events were defined as cessation of airflow for more that 10 s. The AutoSet^{TM} was attached to a computer with available software, and data were automatically downloaded daily creating separate files for each participant per night.

CPAP use during the first week of treatment

The AutoSet^{TM} objectively monitored daily CPAP use. Because we believe the first night of treatment reflected participants' adjustment to the device, we calculated CPAP use during the first week of treatment as average daily use (including 0 h of use) from day 2 to day 7 unless specified otherwise. We conducted additional analyses using average CPAP use calculated from days 1–7 instead of days 2–7, and found similar relationships between CPAP use and the four domains of potential predictors using the two methods.

Statistical analysis

We examined predictors for short-term CPAP therapy from four domains: pre-treatment demographic and clinical factors, patients' perceptions of self-efficacy, treatment delivery and immediate disease reduction. Relationships between the factors in each domain and the outcome variable (average hours of CPAP use during the first week of treatment) were first examined via Pearson's correlation, *t*-test or multiple linear regression, as appropriate. Variables from each domain associated significantly with CPAP use were considered to be retained in the subsequent multiple linear regression analyses to simultaneously test the predictive significance to CPAP adherence. The final multiple linear regression was performed using the backward stepwise method. Binary logistic regression analysis was also conducted by categorizing CPAP use as < or ≥4 h night^{-1}. SPSS version 17.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Statistical significance was defined as $P < 0.05$ using two-tailed tests.

RESULTS

Participant characteristics

The demographic and major clinical characteristics of the sample are summarized in Table 1. Complete data were available for 91 participants. On average, the sample was middle-aged (49.0 ± 12.0 years) and obese [body mass index (BMI) 39.2 ± 10.5 kg m^2]. Approximately half the participants were black (57.1%). The mean AHI for the entire sample was 44.4 ± 36.3 events per hour of sleep, indicating severe OSA. Sixty (65.9%) participants had excessive daytime sleepiness, with an ESS score > 10. On average, the participants had decreased functional status (FOSQ total score 14.7 ± 3.4), compared to a value of <17.9 as the cut-off for abnormal FOSQ total score (Weaver *et al.*, 2007). The number of PVT lapses in this sample (5.5 ± 8.6) is higher than the lapses reported from a community-based adult sample across different age groups (mean range 2.0–2.5), indicating a poor vigilant attention (Kim *et al.*, 2007).

CPAP use during the first treatment week

CPAP use during the first week, calculated as the average daily use from day 2 to day 7, was 3.4 ± 2.7 h with a range from 0 to 9.8 h. Among the 91 participants, 36 (39.6%) used CPAP for ≥4 h, 21 (23.1%) for ≥6 h and 14 (15.4%) for ≥7 h per night.

Pre-treatment characteristics and CPAP use

The average nightly CPAP use in black participants was 1.7 h less than non-black (2.7 ± 2.2 versus 4.4 ± 2.9, $P = 0.003$) participants. Married participants had 1.4 h more CPAP use than those who were not married (4.2 ± 2.8 versus 2.8 ± 2.4, $P = 0.010$). No differences in CPAP use were observed between males and females (3.4 ± 2.6 versus 3.5 ± 2.8, $P = 0.805$). Education and employment status also did not make a difference in adherence to CPAP. Higher ESS score was correlated with poor CPAP use ($r = -0.220$, $P = 0.045$). In addition, a higher FOSQ total score, indicating better overall functional status, was associated significantly with greater CPAP use ($r = 0.288$, $P = 0.006$). CPAP use was not associated with age, BMI, pre-treatment AHI, POMS total score or PVT number of lapses.

The four variables (race, marital status, ESS score and FOSQ total score) that correlated significantly with CPAP use were included in a multiple linear regression model to examine their relationship with CPAP use during the first week of treatment. Collectively, these factors accounted for 19.4% of the variance in CPAP use ($R^2 = 0.194$, $P = 0.002$), with only race (being black) and FOSQ total score significantly predictive of hours of use.

Table 1 Baseline characteristics of the study population

Characteristics	n = *91*
Male, *n* (%)	49 (53.8%)
Black, *n* (%)	52 (57.1%)
White, *n* (%)	38 (41.8%)
With college education, *n* (%)	49 (53.8%)
Married, *n* (%)	42 (46.2%)
Work full-time, *n* (%)	49 (53.8%)
Age, years	49.0 ± 12.0
Body mass index, kg m^2	39.2 ± 10.5
Apnea–hypopnea index, events h^{-1}	44.4 ± 36.3
Epworth Sleepiness Scale	13.7 ± 5.5
FOSQ total score	14.7 ± 3.4
POMS total score	28.4 ± 30.8
PVT number of lapses	5.5 ± 8.6

FOSQ, Functional Outcomes of Sleep Questionnaire; POMS, Profile of Mood States; PVT, psychomotor vigilance task.

Patients' perceptions of self-efficacy and CPAP use

As shown in Table 2, SEMSA scores (risk perception, outcome expectancies and treatment self-efficacy) prior to treatment were not related significantly to use of CPAP at 1 week. However, perception of the ability to engage in the treatment at home (post-treatment self-efficacy) was associated with duration of use ($r = 0.271$, $P = 0.035$), although change scores from pre- to post-treatment for all the subscales were not correlated significantly with CPAP use.

Treatment delivery and CPAP use

The duration of mask leak ≥ 0.2, 0.4 or 0.6 L min^{-1} was not related significantly to CPAP use. Among the 19 treatment side effects examined, less intimacy with partners caused by CPAP (0.5 ± 0.6) was the only treatment side effect correlated statistically with CPAP use ($r = -0.300$, $P = 0.025$).

Immediate disease reduction and CPAP use

Mean residual AHI during the first week was 1.9 ± 3.2, ranging from 0 to 17.7 events per hour. Eight (8.8%) subjects had a residual AHI ≥ 5. Higher residual AHI was correlated significantly with poorer CPAP use ($r = -0.228$, $P = 0.037$). Additionally, having flow limitation at 20% ($r = 0.266$, $P = 0.017$) and 25% ($r = 0.407$, $P < 0.01$) of treatment duration impaired CPAP use. Both variables indicating flow limitation were not correlated significantly with residual AHI.

Final regression model—predictors of CPAP use during first treatment week

Variables associated with CPAP use from each domain were examined simultaneously in subsequent multiple regression analyses to examine significant predictors of week 1 CPAP use, including race, pre-treatment FOSQ total score, post-treatment self-efficacy, treatment side effect of less intimacy with partners, residual AHI and flow limitation. In the final model, reduced CPAP use during the first week was associated with being black, higher residual AHI and the

Table 2 Self-efficacy scores and correlations with continuous positive airway pressure (CPAP) use during the first treatment week

	Pre-treatment			*After 1 week of treatment*		
	Risk perception	*Outcome expectancies*	*Treatment self-efficacy*	*Risk perception*	*Outcome expectancies*	*Treatment self-efficacy*
Scores	2.5 ± 0.6	2.9 ± 0.6	3.0 ± 0.7	2.7 ± 0.6	2.9 ± 0.6	3.1 ± 0.7
Pearson's correlations	−0.077	0.164	0.068	−0.027	0.210	0.271*

*$P < 0.05$.

treatment side effect of less intimacy with partners (Table 3). The strongest predictor was being black, accounting independently for 12.9% of the variability in average hours of CPAP use during the first week of treatment. Mean residual AHI and treatment side effect of less intimacy with partners had a smaller effect on CPAP use (6.6% and 5.8% of the variance, respectively). These three factors together accounted for 25.4% of the variance in initial CPAP use ($P < 0.01$). Similar results were shown in a logistic regression model (CPAP use categorized as < or ≥4 h night^{-1}). The odds of using CPAP ≥ 4 h compared to using it <4 h per night were increased by a factor of 3.9 by being non-black rather than black (95% confidence interval 1.12–13.68, $P = 0.03$) independent of residual AHI (odds ratio 0.64, $P = 0.04$) and less intimacy with partners (odds ratio 0.45, $P = 0.13$).

DISCUSSION

This study adds to the growing literature of CPAP adherence by examining prospectively a wide range of factors predicting CPAP use during the first treatment week, the critical time when the pattern of non-adherence is established for the majority of patients. We find that being black, the treatment side effect of less intimacy with partners and higher residual AHI were the salient factors that affected initial CPAP use. This supports our original hypothesis that multiple pre-treatment and immediate early treatment factors would predict CPAP use during the first week of treatment. The three predictors together accounted for 25.4% of the variance in the CPAP use during the first week of therapy. Similarly, low explanatory power has been reported in other studies investigating multiple predictors of CPAP adherence (Bakker *et al.*, in press; Olsen *et al.*, 2008; Wild *et al.*, 2004). Therefore, adherence to CPAP treatment is a complicated behavior and a large variety of factors may contribute to CPAP use in patients with OSA.

Average daily CPAP use in our study was disappointingly low (3.4 ± 2.7 h), but similar to other reports of prospective studies (Wild *et al.*, 2004). In our investigation of CPAP dose–response the optimal duration of nightly use has been identified to be at least 4 h to normalize subjective sleepiness, 6 h for objective sleepiness and 7 h for functional status (Weaver *et al.*, 2007). Only 39.6% of participants used CPAP for at least 4 h per night, and the proportion decreased sharply to 23.1% for 6-h use and to 15.4% for 7-h use. Previous studies examining CPAP use are predominately retrospective, introducing selection bias. Using patient recall as a subjective measure of adherence may further overestimate CPAP use (Kribbs *et al.*, 1993; Weaver *et al.*, 1997a). With a prospective design and objective monitoring of CPAP use, our findings reflect an alarmingly low level of initial CPAP use that leads to poor adherence in the long term, reinforcing that this is the foremost obstacle in the management of OSA (Weaver and Sawyer, 2010). Moreover, the racial composition of our sample (57.1% black) may partly explain the low hours of CPAP use, as being black was identified as an important predictor of poor adherence in this study.

Similar racial differences have been observed in previous reports of CPAP use (Budhiraja *et al.*, 2007), as well as in studies of adherence to other medical treatment (Heckman *et al.*, 2008; Shenolikar *et al.*, 2006). Greenberg *et al.* (2004) found that 42% of the patients from a minority-serving institution diagnosed with OSA failed to follow-up for treatment, compared with 7% in a voluntary hospital. The issue of why race plays a role in adherence to CPAP remains to be determined. A recent study found that socioeconomic deprivation partly explained the ethnic disparity in adherence to CPAP in New Zealand patients (Bakker *et al.*, in press). Therefore, socioeconomic status, which was not measured directly in this study, may provide a better explanation than race alone. A study conducted in Israel suggested that low monthly income as a risk factor for CPAP acceptance among adults requiring treatment (Simon-Tuval *et al.*, 2009). In a veteran patient population, initial CPAP adherence was associated positively with neighborhood socioeconomic

Table 3 Final regression model—predictors of CPAP use during first treatment week

	β	*Change in R^2*	*Total R^2*	*F*
Being black	−0.319*	0.129	0.254	5.896**
Mean residual AHI	−0.248*	0.066		
Having difficulty being intimate	−0.244*	0.058		

AHI, apnea–hypopnea index.
*$P < 0.05$; **$P < 0.01$.

factors, rather than race or other individual characteristics such as medical comorbidities (Platt *et al.*, 2009). Similarly, in a recent study examining medication adherence in children with newly diagnosed epilepsy, socioeconomic status was identified to be the sole predictor of non-adherence (Modi *et al.*, 2011). We believe that racial differences in the adherence behavior, if present, may be related to multiple factors, including internal (e.g. patient knowledge, beliefs, motivation, health literacy) and external (e.g. socioeconomic status, social support, insurance or medical coverage, barriers to care) factors. A survey conducted in a large cohort of adults with asthma suggested that these internal and external factors related to adherence to medication were different between black and Caucasian patients (Wells *et al.*, 2008). Further studies are needed to confirm the race-related differences in CPAP adherence and elucidate the underlying mechanisms.

We found that married participants had a relatively higher CPAP use than those who were not married. It is likely that married participants had overall higher social support, which has been linked to a better adherence to medical treatment (Dimatteo, 2004). However, instead of marriage status, less intimacy with partners was identified as an independent predictor for reduced CPAP use. Therefore, the nature of spousal involvement in CPAP use may be complicated and cannot be represented simply by marital status. In addition, being married does not automatically imply the existence of a bed partner. The 'collateral damage' of OSA to spouses (e.g. snoring-induced sleep disruption) often leads to patients and their spouses sleeping apart (Billmann and Ware, 2002). In previous reports, we observed that patients demonstrated improved intimacy and sexual relationships following 3 months of CPAP treatment (Reishtein *et al.*, 2010; Ye *et al.*, 2009). However, at least at the beginning of the treatment, less intimacy with partners related to CPAP can be an obstacle to embracing this therapy. This suggests the need to assess the impact of CPAP on intimacy and sexual relationships and discuss with CPAP users methods to enhance this important activity, such as engaging in sexual behavior prior to applying the headgear and commencing therapy. More than many other diseases and treatments, OSA and CPAP treatment affect not only the patients, but also their partners. Recent studies examining bed-sharing and spousal involvement of CPAP treatment have suggested the important impact a partner can have on adherence to CPAP (Baron *et al.*, 2010; Cartwright, 2008). In fact, patients with OSA have described spousal support as an important facilitator, while insufficient spousal engagement as a major barrier to their adherence to CPAP, suggesting the critical need to involve spouses or domestic partners to promote CPAP use (Brostrom *et al.*, 2010).

It remains largely unknown whether CPAP levels prescribed in the sleep laboratory are actually efficacious when the patient applies CPAP at home. Using AutoSet^{TM} to monitor objectively residual respiratory events and airflow limitation during CPAP use at home, we found that high residual AHI was a significant predictor for poor CPAP use during the first week. Unresolved sleep apnea from residual events may lead patients to believe that the treatment is ineffective, resulting in low use or abandoning treatment. This finding underscores the need for close follow-up within the first few days of treatment with evaluation for the presence of residual events and the need for retitration. With the availability of CPAP delivery systems that can monitor efficacy of treatment delivery, it is possible to identify the need for retitration as early as possible to guarantee clinical effectiveness of CPAP treatment.

Although we hypothesized that patients' perceptions of self-efficacy would contribute to their CPAP use, the results did not fully support this hypothesis. In contrast, self-efficacy was emphasized as a strong predictor of CPAP adherence in other studies (Aloia *et al.*, 2005; Stepnowsky *et al.*, 2002). One study found that self-efficacy and other psychological constructs of behavioral change (e.g. knowledge, social support, decisional balance) measured at 1 week post-CPAP-fitting were associated highly with CPAP use over 1 month, but these variables were not associated with CPAP use when measured prior to treatment initiation (Stepnowsky *et al.*, 2002). Social cognitive theory presumes familiarity with the target health behavior (Bandura, 2004), which may explain our observation that perceptions formed within the first week of treatment, but not pre-treatment, influenced adherence in CPAP-naive patients.

Contrary to our findings, greater CPAP use has been reported to be related to greater daytime sleepiness at baseline (Mcardle *et al.*, 1999) or higher improvement in subjective sleepiness following 6 months of CPAP therapy (Kingshott *et al.*, 2000). Although a degree of daytime sleepiness or perceived improvement in symptoms often generates motivation to use CPAP, too much sleepiness itself may interfere with the application of treatment. This finding needs to be confirmed using samples with more variability in symptom severity. Other demographic and clinical factors, such as older age (Budhiraja *et al.*, 2007), male gender (Joo and Herdegen, 2007) and higher baseline AHI (Mcardle *et al.*, 1999) were found previously to be associated with greater CPAP adherence but not in the present study. Different sample characteristics, potential selection bias related to study design and varying length of follow-up time need to be considered when comparing our findings with other studies.

Our study has several limitations. The moderate sample size ($n = 91$) may limit the statistical power for multivariate analyses to rule out other significant predictors of CPAP use which have been described in previous studies. We originally recruited 239 subjects at baseline for this study, but equipment failure associated with the external computer connecting to the CPAP machine which contained the Autoset clinical software occurred in 148 subjects. Major demographic and clinical factors such as age, gender, BMI and AHI did not differ between the 91 subjects and the 148 who were excluded due to the equipment failure. Based on this sample size and with an a priori conservative estimate, five predictors could be identified in a multiple linear regression model. We addressed the issue of limited sample size carefully by choosing variables associated with CPAP use from each of the four domains for subsequent multiple regression analyses, and identified three significant predictors in the final regression model. With a relatively high ratio of black, female and unmarried participants, this sample composition may reflect potential selection bias and limit the generalizability of our finding. Interpretation of the race-related difference in CPAP use is limited by the lack of information related to factors such as socioeconomic status, financial cost of the treatment and health insurance coverage. In addition, other factors such as social support (Dimatteo, 2004), spousal interaction (Baron *et al.*, 2010) and patient experience on the CPAP titration night (Drake *et al.*, 2003) may be important, but were not evaluated in this study.

To our knowledge, this is the first study that attempted to identify multiple factors that influence CPAP use during the first week of treatment. The association of race and CPAP use needs to be examined further by including more socioeconomic information. Assessing the presence of residual respiratory events and the impact of CPAP treatment on intimacy may be important in promoting CPAP adherence. Further studies on developing a practical instrument for detection of patients who are likely to become non-adherent to CPAP and development of maximally effective interventions to enhance the CPAP use are necessary.

DECLARATIONS OF INTEREST

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REFERENCES

Aloia, M. S., Arnedt, J. T., Stepnowsky, C., Hecht, J. and Borrelli, B. Predicting treatment adherence in obstructive sleep apnea using principles of behavior change. *J. Clin. Sleep Med.*, 2005, 1: 346–353.

Aloia, M. S., Arnedt, J. T., Stanchina, M. and Millman, R. P. How early in treatment is PAP adherence established? Revisiting night-to-night variability. *Behav. Sleep Med.*, 2007, 5: 229–240.

Aloia, M. S., Goodwin, M. S., Velicer, W. F. *et al.* Time series analysis of treatment adherence patterns in individuals with obstructive sleep apnea. *Ann. Behav. Med.*, 2008, 36: 44–53.

American Academy of Sleep Medicine. Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. The Report of an American Academy of Sleep Medicine Task Force. *Sleep*, 1999, 22: 667–689.

American Sleep Disorders Association. Practice parameters for the indications for polysomnography and related procedures: Polysomnography Task Force, American Sleep Disorders Association Standards of Practice Committee. *Sleep*, 1997, 20: 406–422.

Bakker, J. P., O'Keeffe, K. M., Neill, A. M. and Campbell, A. J. Ethnic disparities in CPAP adherence in New Zealand: effects of socioeconomic status, health literacy and self-efficacy. *Sleep*, in press.

Baldwin, C. M., Griffith, K. A., Nieto, F. J., O'Connor, G. T., Walsleben, J. A. and Redline, S. The association of sleep-disordered breathing and sleep symptoms with quality of life in the Sleep Heart Health Study. *Sleep*, 2001, 24: 96–105.

Bandura, A. Health promotion by social cognitive means. *Health Educ. Behav.*, 2004, 31: 143–164.

Baron, K. G., Smith, T. W., Berg, C. A., Czajkowski, L. A., Gunn, H. and Jones, C. R. Spousal involvement in CPAP adherence among patients with obstructive sleep apnea. *Sleep Breath*, 2010, [Epub ahead of print].

Billmann, S. J. and Ware, J. C. Marital satisfaction of wives of untreated sleep apneic men. *Sleep Med.*, 2002, 3: 55–59.

Brostrom, A., Nilsen, P., Johansson, P. *et al.* Putative facilitators and barriers for adherence to CPAP treatment in patients with obstructive sleep apnea syndrome: a qualitative content analysis. *Sleep Med.*, 2010, 11: 126–130.

Budhiraja, R., Parthasarathy, S., Drake, C. L. *et al.* Early CPAP use identifies subsequent adherence to CPAP therapy. *Sleep*, 2007, 30: 320–324.

Cartwright, R. Sleeping together: a pilot study of the effects of shared sleeping on adherence to CPAP treatment in obstructive sleep apnea. *J. Clin. Sleep Med.*, 2008, 4: 123–127.

Dimatteo, M. R. Social support and patient adherence to medical treatment: a meta-analysis. *Health Psychol.*, 2004, 23: 207–218.

Dinges, D. F. and Powell, J. Microcomputer analyses of performance on a portable, simple visual RT task during sustained operations. *Behav. Res. Methods Instrum. Comput.*, 1985, 17: 652–655.

Drake, C. L., Day, R., Hudgel, D. *et al.* Sleep during titration predicts continuous positive airway pressure compliance. *Sleep*, 2003, 26: 308–311.

Gottlieb, D. J., Whitney, C. W., Bonekat, W. H. *et al.* Relation of sleepiness to respiratory disturbance index: the Sleep Heart Health Study. *Am. J. Respir. Crit. Care Med.*, 1999, 159: 502–507.

Greenberg, H., Fleischman, J., Gouda, H. E. *et al.* Disparities in obstructive sleep apnea and its management between a minority-serving institution and a voluntary hospital. *Sleep Breath*, 2004, 8: 185–192.

Heckman, B. D., Holroyd, K. A., O'Donnell, F. J. *et al.* Race differences in adherence to headache treatment appointments in persons with headache disorders. *JAMA*, 2008, 100: 247–255.

Johns, M. W. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep*, 1991, 14: 540–545.

Joo, M. J. and Herdegen, J. J. Sleep apnea in an urban public hospital: assessment of severity and treatment adherence. *J. Clin. Sleep Med.*, 2007, 3: 285–288.

Kapur, V., Blough, D. K., Sandblom, R. E. *et al.* The medical cost of undiagnosed sleep apnea. *Sleep*, 1999, 22: 749–755.

Kim, H., Dinges, D. F. and Young, T. Sleep-disordered breathing and psychomotor vigilance in a community-based sample. *Sleep*, 2007, 30: 1309–1316.

Kingshott, R. N., Vennelle, M., Hoy, C. J., Engleman, H. M., Deary, I. J. and Douglas, N. J. Predictors of improvements in daytime function outcomes with CPAP therapy. *Am. J. Respir. Crit. Care Med.*, 2000, 161: 866–871.

Kribbs, N. B., Pack, A. I., Kline, L. R. *et al.* Objective measurement of patterns of nasal CPAP use by patients with obstructive sleep apnea. *Am. Rev. Respir. Dis.*, 1993, 147: 887–895.

Marshall, N. S., Wong, K. K., Liu, P. Y., Cullen, S. R., Knuiman, M. W. and Grunstein, R. R. Sleep apnea as an independent risk factor for all-cause mortality: the Busselton Health Study. *Sleep*, 2008, 31: 1079–1085.

Mcardle, N., Devereux, G., Heidarnejad, H., Engleman, H. M., Mackay, T. W. and Douglas, N. J. Long-term use of CPAP therapy for sleep apnea/hypopnea syndrome. *Am. J. Respir. Crit. Care Med.*, 1999, 159: 1108–1114.

Mcdaid, C., Duree, K. H., Griffin, S. C. *et al.* A systematic review of continuous positive airway pressure for obstructive sleep apnoea–hypopnoea syndrome. *Sleep Med. Rev.*, 2009, 13: 427–436.

Mcnair, D. M., Lorr, M. and Drupplrman, L. F. *EITS Manual for the Profile of Mood States*. Educational and Industrial Test Servises, San Diego, 1971.

Modi, A. C., Rausch, J. R. and Glauser, T. A. Patterns of nonadherence to antiepileptic drug therapy in children with newly diagnosed epilepsy. *JAMA*, 2011, 305: 1669–1676.

O'Connor, G. T., Caffo, B., Newman, A. B. *et al.* Prospective study of sleep-disordered breathing and hypertension: the Sleep Heart Health Study. *Am. J. Respir. Crit. Care Med.*, 2009, 179: 1159–1164.

Olsen, S., Smith, S. and Oei, T. P. Adherence to continuous positive airway pressure therapy in obstructive sleep apnoea sufferers: a theoretical approach to treatment adherence and intervention. *Clin. Psychol. Rev.*, 2008, 28: 1355–1371.

Peppard, P. E. Is obstructive sleep apnea a risk factor for hypertension?—differences between the Wisconsin Sleep Cohort and the Sleep Heart Health Study. *J. Clin. Sleep Med.*, 2009, 5: 404–405.

Platt, A. B., Field, S. H., Asch, D. A. *et al.* Neighborhood of residence is associated with daily adherence to CPAP therapy. *Sleep*, 2009, 32: 799–806.

Redline, S., Yenokyan, G., Gottlieb, D. J. *et al.* Obstructive sleep apnea–hypopnea and incident stroke: the Sleep Heart Health Study. *Am. J. Respir. Crit. Care Med.*, 2010, 182: 269–277.

Reishtein, J. L., Maislin, G. and Weaver, T. E. Outcome of CPAP treatment on intimate and sexual relationships in men with obstructive sleep apnea. *J. Clin. Sleep Med.*, 2010, 6: 221–226.

Shenolikar, R. A., Balkrishnan, R., Camacho, F. T., Whitmire, J. T. and Anderson, R. T. Race and medication adherence in Medicaid enrollees with type-2 diabetes. *JAMA*, 2006, 98: 1071–1077.

Simon-Tuval, T., Reuveni, H., Greenberg-Dotan, S., Oksenberg, A., Tal, A. and Tarasiuk, A. Low socioeconomic status is a risk factor for CPAP acceptance among adult OSAS patients requiring treatment. *Sleep*, 2009, 32: 545–552.

Stepnowsky, C. J., Jr, Marler, M. R. and Ancoli-Israel, S. Determinants of nasal CPAP compliance. *Sleep Med.*, 2002, 3: 239–247.

Weaver, T. E. and Grunstein, R. R. Adherence to continuous positive airway pressure therapy: the challenge to effective treatment. *Proc. Am. Thorac. Soc.*, 2008, 5: 173–178.

Weaver, T. E. and Sawyer, A. M. Adherence to continuous positive airway pressure treatment for obstructive sleep apnoea: implications for future interventions. *Ind. J. Med. Res.*, 2010, 131: 245–258.

Weaver, T. E., Kribbs, N. B., Pack, A. I. *et al.* Night-to-night variability in CPAP use over the first three months of treatment. *Sleep*, 1997a, 20: 278–283.

Weaver, T. E., Laizner, A. M., Evans, L. K. *et al.* An instrument to measure functional status outcomes for disorders of excessive sleepiness. *Sleep*, 1997b, 20: 835–843.

Weaver, T. E., Maislin, G., Dinges, D. F. *et al.* Self-efficacy in sleep apnea: instrument development and patient perceptions of obstructive sleep apnea risk, treatment benefit, and volition to use continuous positive airway pressure. *Sleep*, 2003, 26: 727–732.

Weaver, T. E., Maislin, G., Dinges, D. F. *et al.* Relationship between hours of CPAP use and achieving normal levels of sleepiness and daily functioning. *Sleep*, 2007, 30: 711–719.

Wells, K., Pladevall, M., Peterson, E. L. *et al.* Race-ethnic differences in factors associated with inhaled steroid adherence among adults with asthma. *Am. J. Respir. Crit. Care Med.*, 2008, 178: 1194–1201.

Wild, M. R., Engleman, H. M., Douglas, N. J. and Espie, C. A. Can psychological factors help us to determine adherence to CPAP? A prospective study. *Eur. Respir. J.*, 2004, 24: 461–465.

Ye, L., Pien, G. W., Ratcliffe, S. J. and Weaver, T. E. Gender differences in obstructive sleep apnea and treatment response to continuous positive airway pressure. *J. Clin. Sleep Med.*, 2009, 5: 512–518.

Young, T., Palta, M., Dempsey, J., Skatrud, J., Weber, S. and Badr, S. The occurrence of sleep-disordered breathing among middle-aged adults. *N. Engl. J. Med.*, 1993, 328: 1230–1235.