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Continuous Positive Airway Pressure Treatment for Sleep Apnea in Older Adults

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Abstract

Daytime sleepiness and sleep disordered breathing are increased in older compared to middle-aged adults. The cognitive and cardiovascular sequelae associated with obstructive sleep apnea (OSA) have significant implications for the older adult who may already be suffering from chronic illness. Most of the evidence supporting the utilization of continuous positive airway pressure (CPAP) for the treatment of OSA has been generated from studies employing samples consisting predominately of middle-aged adults. To examine the efficacy of CPAP for the treatment of obstructive sleep apnea in older adults with an emphasis on adherence and related treatment outcomes, this paper reviews findings from clinical trials including older individuals as well as those specifically targeting this population. These studies have demonstrated that following CPAP therapy, older adults have increased alertness, improved neurobehavioral outcomes in cognitive processing, memory, and executive function, decreased sleep disruption from nocturia and a positive effect on factors affecting cardiac function, including vascular resistance, platelet coagulability and other aspects of cardiovascular health. Physiological differences in respiratory structure and function between younger and older adults of similar disease severity are believed to result in older individuals requiring titration at lower CPAP levels. Once initiated, CPAP treatment is tolerated by older adults, including those with Alzheimer's disease. Patterns of adherence in older individuals are consistent with that of middle-aged adults.

Keywords

elderly; CPAP; nasal continuous positive airway pressure; treatment; adherence; outcomes; older adults

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Obstructive sleep apnea (OSA) is as common as diabetes mellitus and typically associated with middle-age. However, while an estimated 20% of middle-aged men have OSA,(1) the prevalence of this sleep related breathing disorder in older adults is greater, ranging from 24 to 42%. (1,2) Older adults have almost a three fold increased risk of having sleep apnea.(1) OSA is associated with significant neurocognitive(3) and cardiovascular sequelae;(3) problems commonly experienced by the general elderly population. Daytime sleepiness, the primary manifestation of OSA, occurs in approximately 9% of adults(4) and results in decreased daily functioning in older adults.(5) Indeed, daytime sleepiness occurs twice as often in individuals older than 75 years compared to middle-aged adults.(4)

Given the prevalence and functional impact of OSA in the elderly, treatment for sleep apnea holds considerable promise. In addition to conservative management, approaches to the treatment of OSA include nasal continuous positive airway pressure (CPAP), oral appliances and surgery. Continuous positive airway therapy is more commonly used as adequate dentition is required for oral appliances and the risk of surgery is increased in those over fifty years of age. The purpose of this review is to examine efficacy of CPAP treatment in the older adult with an emphasis on adherence and related treatment outcomes.

Prescription of CPAP Treatment

Essential to the treatment of OSA is the accurate determination of the apnea-hypopnea index (AHI), the number of apneas and hypopneas that occur per hour of sleep. Night-to-night variability in disturbed breathing has previously been described.(6) Findings from the Sleep Heart Health Study(7) suggest that at lower levels of respiratory disturbances, night-to-night variability is a function of increasing respiratory events and age. In exploring night-to-night variability in disturbed breathing in older adults, Bliwise and collaborators(8,9) showed that a single night polysomnogram may underestimate the absolute value of this parameter. However, other studies of older adults have shown a reasonable level of agreement across nights, (10-12) but also observed a degree of variability among individual patients that may affect clinical management.(10,11) Indeed, this was observed in men more so than women.(12) These data suggest that a single night polysomnography (PSG) may be sufficient for most, but not all older adults and the characteristics that differentiate those for whom a single night may be inadequate need to be further explored.

The prescription for CPAP treatment begins with the titration study to determine the effective pressure to maintain airway patency. Physiological differences between young and older adults are believed to result in older individuals requiring lower CPAP levels than younger persons at a similar level of disease severity.(13) There is a decrease in chest wall compliance with aging associated with calcification and other structural changes.(14) Age-related osteoporosis also results in a change in the shape of the thorax.(14) Although these changes make the lungs less compliant, the diminished elastic recoil of the lung parenchyma makes them more distensible resulting in breathing at higher lung volumes than younger individuals.(14) The association between lung volume and upper airway cross-sectional area may require lower effective CPAP pressures in older adults who may not experience the upper airway collapsibility and inspiratory airflow resistance associated with reduced lung volumes during sleep in younger individuals, as hypothesized by Kostikas and colleagues(13) Testing this hypothesis, they compared the pressure requirements of 70 elderly (mean age 68.1 ± 3.6 SD) with 70 younger individuals (mean age 34.7 ± 4.1). They demonstrated that the pressure required for the older patients was significantly lower than that required for the younger ones (6.9 vs. 9.3 cm H_2O).(13) There were no differences between the two age groups in body mass index, neck circumference or apnea-hypopnea index (AHI) measured during the in-home diagnostic sleep study or unattended titration study utilizing an autoadjusting device.

The results obtained by Kostikas and colleagues(13) differ from previous investigations employing statistical modeling to identify factors, including age, that are operative in the determination of therapeutic pressure.(15-17) For the most part, the samples from the studies where age was not associated with pressure comprised middle-aged individuals, although the age range included those over the age of 60. However, with fewer older adults in the sample the effect of age in determining effective pressure may have been blunted. In contrast, by comparing matched cohorts of younger and older adults, Kostikas and colleagues were more directly able to document the contribution of age to the determination of therapeutic pressure.

Efficacy of CPAP Treatment

A recent review of the literature evaluating the efficacy of CPAP treatment demonstrated the positive impact of CPAP on the apnea-hypopnea index, sleep architecture, daytime sleepiness, quality of life, neurobehavioral performance and psychological effects, and cardiovascular morbidity(see Table 1) .(18) The majority of the clinical trials reviewed for the practice parameters were conducted primarily in the middle-aged population.(18)

Given the number of clinical trials now available for review, with the exception of the section below on nocturia where this outcome has not been investigated under controlled conditions, the following sections review the evidence from controlled (placebo, conservative therapy, normal controls) studies regarding the efficacy of CPAP treatment where age greater than or equal to 65 years was not a study exclusion.(see Table 2). Of the 26 studies,(19-43) eight (19-25,44) selected tablets as controls, 13 used sham or subtherapeutic CPAP with pressure ≤ 2 cm H_2O,(27-36,39,42,43) four compared CPAP to conservative therapy (weight control and nasal strips),(26,37,40,41) and one employed healthy individuals.(38)

Apnea/Hypopneas and Sleep Architecture

As displayed in Table 2, in studies that did not exclude individuals 65 or older, CPAP was more effective in reducing the number of apneic and hypopneic events than the controls.(20, 29,37,39) Compared to tablet placebo, CPAP decreased stage 1 and increased stage 3 and 4 sleep.(20,25) These studies suggest that CPAP is effective in eliminating apneas and hypopneas associated with OSA and positively affects sleep architecture in studies including older adults.

Daytime Sleepiness

Predominantly employing the self-report measure, the Epworth Sleepiness Scale (ESS), as the metric for subjective daytime sleepiness, controlled studies including older individuals found consistent evidence that CPAP was superior to placebo(20,23-27,29,30,32,33,44) as well as conservative treatment to improve alertness.(26,37) (see Table 2)

As shown in Table 2, only one study has examined the efficacy of CPAP in a purely older population (mean age 78 ± 7.04 years), uniquely in a sample of OSA patients (mean (SD) RDI = 28.5 ± 17.2) who also had Alzheimer's disease (National Institute of Neurological and Communicative Disorders & Stroke – Alzheimer's Disease and Related Disorders Association criteria).(29) Employing sham-CPAP as the control with pressure ≤ 0.5 cm H_2O, 39 subjects were randomly assigned to placebo or active CPAP treatment. In this single cross-over 3-wk intervention study, there was significant improvement in the ESS in the active (p= 0.04), but not the placebo group (p = 0.33) compared to baseline. Following the cross-over of the sham-CPAP group to 3 wk active therapy, there was a significant decline in daytime sleepiness (p = 0.01). The group originally allocated to active treatment continued to improve with an additional 3 wk of treatment (p = 0.004). This study not only suggests that older individuals with OSA benefit from CPAP treatment, but those with the additional burden of Alzheimer's disease can utilize this therapy achieving gains in alertness.

Both the Multiple Sleep Latency Test (MSLT)(19,21-23,27,37,41) and Maintenance of Wakefulness Test (MWT)(20,30,32,44) have measured objective sleepiness in studies including older adults. CPAP does not appear to affect objective sleepiness when compared to conservative therapy.(37,41) Controlled studies employing either tablets(19-21,23,44) or sham-CPAP(27,30,32) as placebos were more equivocal. For example, studies of patients with no subjective sleepiness(27) or more mild disease(19,20,22,44) failed to show improvement in objective sleepiness with CPAP treatment, compared to those with more severe disease.(21,23,30,32) CPAP appears to be beneficial in improving self-reported daytime sleepiness in older adults and even in those with dementia, but evidence does not show that it is superior to conservative therapy or placebo for increasing objectively measured daytime sleepiness.

Self-Reported Symptoms

A few controlled studies that included older individuals have examined the effect of CPAP on self-reported symptoms of OSA (see Table 2), such as snoring, daytime sleepiness, gasping, and witnessed apneic events. Employing investigator-developed questionnaires, two randomized studies found CPAP treatment to be superior to conservative therapy(26,41) and several studies utilizing placebos found that CPAP produces a greater reduction in symptoms than placebo.(19-23,44) Thus, the meager evidence that exists suggests that CPAP does positively affect self-reported symptoms in older individuals.

Neurobehavior and Mood

There have been a number of studies including older adults as participants that have examined the impact of CPAP therapy on neurobehavioral functioning compared to controls.(19-23,27,30,31,41,44) Only one study investigated the impact of conservative treatment versus CPAP therapy and found that cognitive processing, memory, and executive function were more positively affected by this treatment.(41) Among studies employing either a tablet or sham-CPAP as placebos,(19-23,27,30,31,44) the results are inconsistent. Several studies found CPAP superior for cognitive processing,(20-22,44) while others did not.(21,23,27,31) There were also mixed results for sustained attention(19,20,22,23,27,30,31) and mood.(19-23,44) The conflicting results are likely related to insufficient statistical power resulting in a Type II error.

One small study (n = 12) examined the relationship between objectively measured CPAP use over 3 mo and cognitive improvement in individuals older than 55 years who had OSA.(45) Based on the median split of 6 h, participants were divided into two groups, compliant and non-compliant users. Of the battery of tests that included measures of attention, constructional abilities, motor speed, memory, language, and executive functioning, only measures of motor speed during attentional tasks, and nonverbal learning and memory demonstrated significant improvement with compliant use. Although CPAP appears to be superior conservative treatment in enhancing neurobehavior in older adults, results from randomized controlled trials inconclusive regarding. This may be due to small sample size and the aspects of neurobehavior evaluated.

Functional Status and Quality of Life

Quality of life and its component, functional status, were outcomes frequently measured in controlled trials involving older OSA patients. These studies employed both generic measures such as the SF 36, which assesses physical functioning, mental health, role functioning, social functioning, pain, vitality, and mobility, and disease specific measures, commonly the Functional Outcomes of Sleep Questionnaire that examines the impact of daytime sleepiness on general productivity, activity level, vigilance, social outcome, and intimate and sexual relationships, to operationally define functional status and quality of life. These studies were inconsistent in their results as to whether CPAP enhances daily functioning better than conservative measures,(26,37,41) tablet(19-24,44) or sham/subtherapeutic-CPAP in this population of patients.(27,33,36)

Cardiovascular Factors

Those with OSA are at an increased risk of cardiovascular disease.(46) Understanding how CPAP therapy mitigates that risk is critically important for the care of older adults who are particularly vulnerable to cardiovascular events. Several studies have explored the impact of CPAP treatment on blood pressure.(20,24,27,28,34,35,43) In studies that included older adults, there are differing results regarding the impact of CPAP on this important variable, likely attributable to level of disease severity, sample size, and duration of intervention. While some studies have reported decreases in mean arterial blood pressure with CPAP treatment(28,35) others found no change in this parameter.(20,24,27,34,43) Improvements over placebo have been demonstrated for daytime and sleep time diastolic pressure.(24,28,35) Two studies reviewed did not find that CPAP affected systolic blood pressure, both daytime and sleep time, compared to placebo,(24,28,43) but one other observed improvement in overall systolic and diastolic pressure.(35) A recent study of the effect of CPAP treatment on blood pressure in non-sleepy patients, defined as an ESS < 10, whose sample included older individuals, failed to observe an effect of active treatment on blood pressure compared to sham-CPAP.(43) Previously demonstrating that CPAP positively affected blood pressure in a sample that included sleepy participants,(35) the investigators suggested that the impact of CPAP on this outcome may be mechanistically related to daytime sleepiness. This possibility has implication for the treatment of sleep apnea in older adults where there is a higher prevalence of sleep disordered breathing in older compared to middle aged adults,(3,47) but who experience less daytime sleepiness.(4,48)

Nelesen and associates studied cardiac function prior to and following a stressor in placebo versus CPAP treated groups.(34) With intervention, the CPAP treatment group showed higher parasympathetic activity, lower heart rate, better cardiac contractility, increased stroke volume, and decreased systemic vascular resistance. Similarly, Ziegler and co-investigators demonstrated that CPAP treatment reduced daytime heart rate.(39) Compared to sham placebo, the CPAP treated group had a reduction in sympathetic activity with decreased plasma and daytime, but not nighttime, urine norepinephrine levels accompanied by increased beta $_2$ adrenergic-receptor sensitivity. However, they found no differences in epinephrine responses, beta-receptor density, or alpha-receptor sensitivity.

Two studies evaluated the impact of CPAP treatment on circulating cardiovascular risk factors. In their comparison of unmatched normal controls with participants having OSA, Robinson and colleagues found elevations only in activated coagulation factors XIIa, VIIa, soluble P-selectin, and thrombinantithrombin complex.(42) After randomly assigning the OSA participants to either 4 wk of subtherapeutic CPAP (< 1 cm H_2O pressure) or active treatment, only factor VIIa decreased following intervention, but only in those treated with subtherapeutic CPAP. Factor XII also fell with treatment, but again only in the subtherapeutic treatment group. The reason why these changes occurred in the placebo group was unclear. There was also a decrease in cholesterol following active treatment, but it was not statistically different from the placebo. However the 0.28 mmol/l fall in total cholesterol after 4 wk of CPAP treatment represents a 15% reduction in risk of ischemic heart disease for a 60 year old and similar to that obtained with dietary control.(42) In another study, there were no differences in hematocrit, whole blood viscosity, platelet aggregation, blood coagulability and fibrinogen between healthy controls and OSA patients treated with CPAP.(38)

These findings, collectively, suggest that CPAP treatment has a positive effect on those factors affecting cardiac function, including vascular resistance, platelet coagulability and other aspects of cardiovascular health. Whether nonsleepy older adults with sleep apnea should be treated to protect from cardiovascular events remains a topic of further investigation.

Nocturia

Nocturia, awakening from sleep to voluntarily urinate, is a common problem for older adults. Although nocturia is frequently attributed to bladder problems, it is especially prevalent and severe in persons with OSA. In OSA, the increased negative intrathoracic pressure that occurs with apneas results in increased venous return and atrial stretch.(49) These produce a false symptom of fluid volume overload and trigger the secretion of atrial natriuretic peptide causing the kidneys to increase urine production with an increased loss of water and sodium.(49) Therefore, the nocturia that occurs with OSA is not just voiding because of being awake but is the result of a full bladder and the normal need to empty. There have been no controlled studies of the effect of CPAP treatment on nocturia. However, two intervention studies found that treatment with CPAP resulted in decreased night time voiding.(50,51) For example, based on symptom questionnaire data assessed prior to and after 4 mo CPAP treatment, Kiely and colleagues found that OSA patients experienced a significant decline in self-reported frequency of getting up at night to void and overall nightly frequency of passing urine.(51) A comparison group consisting of untreated OSA patients matched for age, body mass index, ESS and AHI did not report improvement in symptoms for the same time period. Although objectively measured data is lacking as is controlled clinical trials, the few studies that have examined the impact of CPAP on nocturia have found that it decreases the frequency of nocturnal voiding. Further study is needed to generate conclusive, Level I evidence, of the value of CPAP in reducing nocturia.

Adherence to CPAP Treatment

Table 3 describes factors associated with CPAP adherence. The role of age in predicting adherence to CPAP treatment remains unclear. After 3 mo of use, of those less than 60 years 92% were adherent to CPAP compared to 81% of users greater than 60 years.(48) The pattern of increased use by those less than compared to those greater than 60 years persisted after 6 mo, 1 and 3 years.(48) However, in other studies age has not consistently been predictive of CPAP use.(52)

In a chart review of 33 patients prescribed CPAP therapy, Russo-Magno and co-workers investigated the nature of compliance specifically in older men (age >65 yrs).(53) Defining compliance to treatment as use greater than 5 h per night based on the last 6 mo hour meter readings, significant differences in nightly CPAP duration were found between compliant and noncompliant patients (7.5 h ± 7.5 SE vs. 0.2 h ± 0.1, respectively). Therapy was initiated at a younger age in compliant versus noncompliant patients. There was no difference between the two groups with regard to having a spouse or co-habiting partner. More of the noncompliant patients were smokers and complained of nocturia. Diuretic medication was greater in the compliant group, but benign prostatic hypertrophy was more common in those who were noncompliant. The authors suggest that the frequent trips to the bathroom associated with benign prostatic hypertrophy and the necessity of having to remove and reapply headgear may have contributed to limited use of CPAP by this group. Those patients who participated in the education and support group held every 6 mo were more compliant than those who did not. The sessions consisted of a self-report of CPAP use, review of self-reported symptoms and complications of CPAP treatment, question and answer session, and a lecture on a topic related to their disorder. At these sessions, the mask interface was changed if warranted.

As discussed above, CPAP therapy has been shown to be beneficial in improving some aspects of neurobehavior in studies including older adults.(45) Based on this evidence, Ayalon and coworkers questioned whether those with cognitive impairment, particularly those with Alzheimer's disease, could employ CPAP treatment.(54) Thirty patients, 50 – 91 years, with possible-or-probable mild-to-moderate Alzheimer's Dementia diagnosed by a neurologist according to National Institute of Neurological and Communicative Disorders and Stroke criteria with a Mini Mental Status Examination score greater or equal to 18 and AHI ≥ 10 participated in the study designed to study this question. Participants were randomly assigned to receive either active or sham-CPAP therapy. There were no significant differences in CPAP adherence between the two groups with the average use for the entire cohort of 4.8 ± 2.1 h per night. Those who continued CPAP after the 3-wk study had significantly higher CPAP use than those who did not (5.5 h ±1.5 vs. 3.7 ± 1.8, respectively). In this study, CPAP adherence was only associated with the presence of depressive symptoms on treatment with adherent individuals having fewer symptoms ($p<0.04$).

Only one study has evaluated an intervention designed to improve adherence specifically in older adults.(55) Aloia and associates employed an intervention to affect the patients' cost/benefit analysis or decisional balance regarding CPAP treatment.(55) There were no significant age differences between those participants randomly assigned to the intervention (mean age 63.4 ± 4.5) or control (mean age 67.6 ± 4.7) groups. Both groups underwent two 45-min sessions. During the first experimental session, prior to treatment, the experimental group was educated on their severity of sleep apnea, efficacy of CPAP based on the titration night, and symptom manifestation, including their neurobehavioral performance. The second experimental session reviewed information regarding their compliance with CPAP during the first week, changes noticed with CPAP treatment, and individually addressed any issues with regard to obstacles encountered in using CPAP. The control group, matched for age, education, and disease severity, received general information regarding sleep architecture and their opinion of the sleep clinic during both sessions. There were no significant differences in adherence between the two groups at weeks 1 or 4, but significance was achieved at week 12. Participants in the experimental group employed their CPAP 3.2 h longer than the control subjects ($p < 0.04$) with a large effect achieved (d =1.27). It is unclear why the intervention took so long to affect behavior, but the authors speculated that this reflected the length of time necessary to process the provided information. The authors concluded that the intervention positively affected the decisional balance of the experimental group in favor of CPAP therapy. Although there has been limited exploration of ways to improve CPAP adherence in older OSA patients, we have included in Table 4 interventions that might be potentially helpful in promoting CPAP use.

Conclusion

Documented by this review, there is a paucity of data regarding CPAP treatment in older sleep apnea patients. There have been few investigations of CPAP patterns of use in this population as well as whether outcomes achieved with younger individuals are also true in older patients who may be less sleepy, have a higher apnea and hypopnea index, and suffer from more co-morbidities. Whether reductions in daytime sleepiness demonstrated for older CPAP-treated patients will result in increased functioning and reduced disability is unknown. It also remains unclear whether older individuals are less adherent to treatment and, if so, what interventions should be employed in this group of patients who may experience more cognitive and physical impairment. More research is needed on initiation of CPAP treatment in the elderly and evaluation of various outcomes, especially among different levels of disease severity.

Practice Points

1. Older individuals can utilize CPAP as well as younger patients and should be used throughout the sleep duration every night.
2. Adherence should be monitored with objective data of mask-on use, especially during the first week of treatment.
3. Patients should receive a thorough explanation of the purpose of the treatment, application of the treatment with return demonstration, and care of the head care and equipment
4. Including the partner in the education and follow-up may increase acceptance of CPAP treatment.
5. Troubleshooting any problems and reviewing outcomes observed with CPAP treatment along with participation in a support group may promote use.

Research Agenda

In the future, research, especially clinical trials, should not only include but target older adults and:

1. Describe the immediate and long-term benefits of CPAP treatment in the elderly across levels of OSA severity including:
    a. Cardiovascular outcomes
    b. Cognitive and psychological outcomes
    c. Social and functional outcomes
2. Identify whether the response to treatment is similar between older and younger adults.
3. Determine which patients should receive treatment with consideration of treatment severity and extent of daytime sleepiness.
4. Describe the patterns of adherence in elderly patients and identify factors that influence adherence in this age group.
5. Determine if there are complications to CPAP treatment that are unique to the elderly patient.
6. Test interventions that promote adherence in elderly patients.
7. Examine whether gains in cognitive functioning following CPAP therapy can be achieved in older adults with cognitive impairments, such as Alzheimer's disease or stroke.
8. Determine whether self-management of chronic illnesses such as diabetes or heart failure can be improved by increasing alertness with CPAP treatment

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Table 1

Potential Benefits of CPAP Treatment for OSA

Potential Benefits of CPAP Treatment for OSA
◇ Increased subjective and objective alertness
◇ Decreased risk for cardiac disease and stroke
◇ Decreased risk of developing hypertension
◇ Improved neurobehavioral outcomes in cognitive processing, memory, learning, sustained attention and executive function
◇ Improved mood
◇ Improved functional outcomes
◇ Decreased nocturia
◇ Decreased risk of sleepiness related accidents

Table 2

Controlled Studies of CPAP Efficacy in OSA Permitting Participants ≥ 65 years

Study	Age Criteria/ Mean Age (Years) (Range, if provided)	Sample Size (Completed Study)	Mean AHI	Control/ Duration of Intervention	Adherence	Results
Ballester et al., 1999(26)	No age criteria/ 53 ± 10 SE	105 (CPAP 68; Cons. Tx 37)	56 ± 20	Conservative Tx (weight loss, sleep hygiene)/3 mo	CPAP > 4.5 h/night	Significant differences subjective sleepiness, self-reported symptoms, day time function.
Barbé et al., 2001(27)	No age criteria/ 54 ± 2 SE (CPAP); 52 ± 2 SE (Sham CPAP)	55 (29 CPAP; 25 Sham)	CPAP 54 ± 3 SE; Sham CPAP 57 ± 4 SE	Sham-CPAP /6 wks	CPAP 5 ± 0.4 h/day; Sham-CPAP 4 ± 0.5h/ day	No statistical difference between interventions for 24 hr blood pressure, quality of life; subjective and objective sleepiness, neurobehavioral battery except one of four addition tasks.
Barnes et al., 2002(19)	> 18 years/45.5 ± 10.7 SE	42(28)	12.9 ± 6.3	Tablet placebo/8 wks	CPAP 3.53±2.13 h	Active CPAP treatment was superior to placebo for self-reported symptoms, but not for subjective and objective sleepiness, memory, cognitive processing, executive function, sustained attention, mood, or quality of life.
Barnes et al., 2004(20)	No age criteria/47 + 0.9 SD	104 (80 completed all 3 tx arms- placebo, or alappliance, CPAP)	21.3 + 1.3	Tablet placebo/3mo	CPAP 3.6 ± 0.3 h/night	Compared to placebo, CPAP improved AHI and hypoxemia; reduction in stage 1sleep and increase stage 3 & 4 sleep subjective sleepiness; self-reported symptoms; sustained attention, mood; quality of life, and cognitive processing. No improvement in objective sleepiness, some neurobehavioral tests, or blood pressure
Becker et al., 2003(28)	No age criteria/ CPAP 54.4 ± 8.9 SD, Subtherapeutic CPAP 52.3 ± 8.4	60(32, 16each tx arm)	CPAP=62.5 ±17.8; Subtherapeutic CPAP =65.0 ± 26.7; Therapeutic=65.2 ± 17.8	Subtherapeutic CPAP (lowest pressure setting of device used)/9 wks	CPAP 5.5 ± 2.0 h/ night;Subtherapeutic 5.4 ± 2.2 h/night	Greater change from baseline with active vs. subtherapeutic CPAP in: mean arterial blood pressure; mean systolic and diastolic; mean daytime BP; daytime diastolic; mean nighttime BP, mean night time diastolic, AHI, subjective sleepiness, mean SaO_2. There was no significant change in mean daytime and nighttime systolic pressure, total sleep time, or increases in percentage of sleep stages.
Chong et al., in press(29)	Not stated/78 (53-91) CPAP 77.68 ± 6.9 SD ; Sham CPAP 77.85 ± 7.3	39	28.5 ± 17.2/CPAP 30.7 ± 17.8; Sham CPAP 26.4 ± 16.6	Sham CPAP 0 - 0.5 cm H_2O/ 3 wk	CPAP 5.2 ± 2 h/night	Active CPAP was more effective than sham CPAP in reducing the RDI and subjective sleepiness
Engleman et al., 1994(21)	No agecriteria/49 ±1.5 SE	35 (32)	Median AHI 28 (7 – 129/h)	Tablet placebo/4 wk	CPAP 3.4 ± 0.4 SE	Compared to placebo, CPAP improved self-reported symptoms; objective sleepiness; mood; quality of life; energetic arousal. There was no significant difference in cognitive processing.
Engleman et al., 1997(22)	No age criteria/52 ± 2 SE	18(16)	11 ± 1	Tablet placebo/4 wk	CPAP 2.8 ± 0.6 SE hours per night	CPAP was more effective than placebo for the outcomes: self-reported symptoms; executive

Study	Age Criteria/ Mean Age (Years) (Range, if provided)	Sample Size (Completed Study)	Mean AHI	Control/ Duration of Intervention	Adherence	Results
						function; and depressed mood. No significant change was noted for objective and subjective sleepiness, sustained attention, perceived general health, and quality of life
Engleman et al, 1998(23)	No age criteria/47 ± 12 SD	23(23)	43 ± 37	Tablet placebo/4 wk	CPAP 2.8 ± 2.0 SD hrs/ night	Compared to placebo, CPAP superior for objective sleepiness; subjective sleepiness; self-reported symptoms. No significant difference was observed for neurobehavioral performance, mood, and quality of life.
Engleman et al., 1999(44)	No age criteria/44 ± 8 SD yrs	37(34)	10 ± 3	Tablet placebo/4 wk	CPAP 2.8 ± 2.1 hr/night	Compared to baseline, CPAP was superior to placebo for self-reported symptoms; subjective sleepiness; cognitive processing; depressed mood; and health status/functional status. No statistically robust change for objective sleepiness, and executive functioning,
Faccenda et al., 2001(24)	No age criteria/ median 50(29-72)	71(68)	median 35(15-129)	Tablet placebo/4 wk	CPAP 3.3 hr/night (range:0-8.1 hr	CPAP produced significantly greater changes in diastolic (but not systolic or mean arterial pressure); subjective sleepiness; and functional status
Hack et al., 2000(30)	Between ages 30 – 75 years/CPAP 50 (38 –68); Sham CPAP 50 (35 – 64)	69(59)	CPAP 26.1 (12.6 – 55.5); Subtherapeutic CPAP 34.7 (11 – 70)	Sub therapeutic CPAP delivering 0.5 - 1 cm H_2O/ 1 mo	Active CPAP median 5.6 (3.0 – 7.2) h/night; Sub-therapeutic 5(1.2 – 8.5) h/night;	Significance pre/post differencesubtherapeutic vs. active CPAP intracking; sustained attention; subjectiveand objective sleepiness, but not reaction time.
Henke, et al., 2001(31)	No age criteria/ CPAP 50.2 ± 10.4 SD; Sham CPAP 50.6 ± 9.7 SD	45(39)	CPAP 62.1 ± 27.4 SD; Sham CPAP 68.1 ± 25.2 SD	16 days ActiveC PAP pressure vs.14 days Sub-therapeutic CPAP (0-1 cm H_2O)	CPAP 5.9 ± 1.8 SD h/ day ; sham-CPAP5.2 ± 2.2 SD h	No differences between the two interventions for neurobehavior or subjective sleepiness.
Jenkinson et al., 1999(32)	Between 30 – 75 years of age/CPAP 50 (33-71); Sham CPAP – median 48 (36-68)	107 (101)	> 4% SaO_2 CPAP 32.9 (15.5-64.4); Sham CPAP 28.5 (10.7-68.7)	Subtherapeutic CPAP (1 cm H_2O)/4 wk	CPAP – median 5.4 hrs/ night; Subtherapeutic CPAP 4.6 hrs/night	Significant pre/post between CPAP and subtherapeutic for subjective and objective sleepiness; oxygen saturation; and health status
Kajaste et al., 2004(40)	No age criteria/ CPAP 50.1 ± 7.9SD, wt. loss 47.9 ± 8	33(31)	ODI_4CPAP 47.9 ±33.5 SD; wt. loss 55.5 ± 28.5	Very low calorie diet and cognitive behavioral therapy/ 24 mo	CPAP every night by self-report	No significant difference between interventions for ODI_4 values or emotional well-being
McArdle et al., 2001(25)	No age criteria/53 ± 11 SD	23(22)	median 40 (IQR 25-65)	Tablet placebo/4 wk	median CPAP use 4.5 (IQR 2.6-6.2) h/night	Significant differences CPAP vs. placebo in sleep architecture (less stage 1; increased stage 3+4); self-reported feeling of being more refreshed; subjective sleepiness
Monasterio et al., 2001(41)	No age criteria/54 ± 9 SD	142 (125)	CPAP 20 ± 6;conservative tx 21 ± 6	Conservative measures (weight loss [home diet if BMI >27]; sleep hygiene)/6 mo	4.8 ± 2.2 h/d	Significant differences between cons tx vs. CPAP intervention for self-reported symptoms at 3 & 6 mo; memory at 3 mo; executive function at 3 mo. No significant differences noted for subjective and objective sleepiness, vigilance, daily functioning, or quality of life.

Study	Age Criteria/ Mean Age (Years) (Range, if provided)	Sample Size (Completed Study)	Mean AHI	Control/ Duration of Intervention	Adherence	Results
Montserrat et al., 2001(33)	No age criteria/54.2 ± 10.2 SD CPAP 55.65 ± 9.41 (28-74) Sham CPAP 52.59 ± 10.93	48(45)	53.8 ± 19.3/CPAP 50.52 ± 19.83; Sham CPAP 57.14 ± 21.14	Sham CPAP	Active CPAP 4.25 ± 2; Sham CPAP 4.5 ±2	Greater improvement was demonstrated for subjective sleepiness; self-reported symptoms; functional status, but not for perceived health status.
Nelesen et al., 2001(34)	No age criteria/50 ± 2.2 SE	41/CPAP 23; Sham CPAP 18	39 ± 4.7 SE	Sham CPAP 2 cm H_2O/8 days	Active CPAP 6± 0.2; Sham CPAP6± 0.2	Compared to placebo, active CPAP produced significant lowering of lower heart rate; greater high frequency power; increased respiratory sinus arrhythmia; improvement in cardiac contractility, and stroke volume. In response to a stressor, the CPAP treated group compared to placebo had lower sinus arrhythmia; higher cardiac acceleration index preejection period, low frequency/high frequency ratio; lower systemic vascular resistance; and higher cardiac output. No significant differences in mean arterial blood pressure
Pepperell et al., 2002(35)	30 – 75 yrs /CPAP 50.1 ± 10.4 SD; Subtherapeutic CPAP 51.0 ± 9.8	137 (104)	>4% oxygen saturation dips/h sleep CPAP 38± 19.8; Subtherapeutic 35.9 ± 19.6	Subtherapeutic CPAP < 1 cm H_20/4 wk	Active CPAP 4.9 ± 2.0; Subtherapeutic CPAP 4.5 ± 2.4	Significant differences in change from baseline between treatments in 24-h mean blood pressure; sleep period mean blood pressure; wake period mean blood pressure; overall systolic blood pressure; overall diastolic blood pressure
Profant et al., 2003(36)	30-65/ CPAP 47.7 ± 8.1 SD; Sham CPAP 48.7 ± 9.9	39	CPAP 53.6 ± 23.2; Sham CPAP 41.7 ± 25.6	Sham CPAP ≤ 2cm H_2O/7 days	> 5 hr/night for each group	Active treatment significant reduced RDI, but not quality of life.
Redline et al., 1998(37)	25 -65/ 48 ± 9.8 SD	114 (97)	13.3 ± 9.8	Conservative tx (mechanical nasaldilators)/CPAP10.8 ± 2.7 wk; conservative tx 10.1 ± 1.8 wk	Nasal dilator self-reported use 82 ± 26%of intervention nights; Mean CPAP use 3.1 h/ night	Significant differences between cons tx and CPAP were change from baseline in: RDI; oxygen saturation nadir; subjective sleepiness, and functional status. No change in objective sleepiness.
Robinson et al., 2004(42)	30 – 75 yrs/ subtherapeutic CPAP group 49.1 ± 10.3 SD; therapeutic CPAP 49.7 ± 10.3 yrs	220 (112 subtherapeutic CPAP; 108 therapeutic CPAP	Oxygen desaturation dips >4%/hr sleep subtherapeutic = 38.5 ± 20.3; therapeutic CPAP 38.9 ± 21.1	Subtherapeutic CPAP < 1 cm H_20/4 wk	Subtherapeutic CPAP = 4.1 ± 2.4; therapeutic CPAP 5.0 ± 1.9 h/night	Levels of coagulation factors VII a and XII fell in the sub therapeutic but not therapeutic CPAP group. There were no differences between the groups in factor XIIa, soluble P-selectin or thrombin-antithrombin complex. There were no differences between the groups for cholesterol and triglyceride.
Robinson et al., 2006(43)	> 18 yrs/54 ± 8 SD yrs	35 (32; 16 subtherapeutic CPAP; 16 therapeutic CPAP)	Median oxygen desaturation dips >4%/hr sleep = 28.1 (IQ 18.0 – 38.0)	Subtherapeutic CPAP < 1 cm H_20/4 wk	Subtherapeutic CPAP = 4.3 ± 2.4 ;therapeutic CPAP 5.2 ± 2.1 h/night	No differences between groups for 24 h mean blood pressure, daytime or sleep time blood pressure, 24 h systolic or diastolic pressure.
Zhang et al., 2003(38)	No age criteria/ OSA 63.4 ± 4 SD	41 (32 healthy controls)	37 ± 9.6	Healthy normal controls without OSA or cardiocerebral disease	Not stated	After CPAP tx, compared to healthy controls, there was no difference at 6 AM or 4 PM in hematocrit, whole

Study	Age Criteria/ Mean Age (Years) (Range, if provided)	Sample Size (Completed Study)	Mean AHI	Control/ Duration of Intervention	Adherence	Results
	(60 – 74); Controls 63.8 (60 – 73)					blood viscosity, platelet aggregation, blood coagulability and fibrinogen.
Ziegler et al., 2001(39)	35-64/CPAP 48.3 ± 1.4 SE; Sham CPAP 49.7 ± 2.2	38	CPAP 54 ± 5; Sham CPAP 39 ±5	Sham CPAP < 2cm H_2O/ 10 days	Not reported	Compared to placebo, CPAP significantly lowered RDI; daytime, but not nighttime, heart rate; decreased plasma and daytime, but not nighttime urine norepinephrine levels; increased $beta_2$-adrenergic-receptor sensitivity. There were no differences in epinephrine responses, beta-receptor density, or alpha-receptor sensitivity..

Table 3

Factors Associated with CPAP Compliance

Factors Associated with CPAP Adherence	
Low Adherence	**High Adherence**
◇ Depression	◇ Treatment initiated at younger age
◇ Claustrophobia or mask intolerance	◇ Education about risks of untreated OSA
◇ Nasal stuffiness or irritation	◇ Education about potential benefits of CPAP treatment
◇ Increased frequency of nocturnal voiding	◇ Early evaluation of CPAP adherence and potential problems
	◇ Individualized interventions to address barriers to adherence

Table 4

Interventions to Improve CPAP Adherence

Interventions to Improve CPAP Adherence
◇ Increase awareness of health care providers of the signs, symptoms, and risks of OSA to improve early identification and evaluation of persons suspected of having OSA
◇ Evaluate candidates for CPAP for potential barriers such as increased nasal resistance and refer for treatment if appropriate
◇ Assess for psychological causes for poor adherence such as claustrophobia or depression
◇ Educate on risks of OSA include increased risk for cardiovascular disease, hypertension, neurobehavioral problems, increased risk for car crashes, decreased mood, impaired functional outcomes including decreased desire and ability for sexuality and intimacy – link disabilities and risks associated with OSA with ability to conduct daily activities
◇ Educate on benefits of CPAP treatment including decreased daytime sleepiness and improved functioning
◇ Utilize humidification on CPAP machine to reduce nasal symptoms
◇ Assess CPAP adherence during the first week of treatment and utilize objective information from CPAP adherence monitor to review adherence record and set goals for improved adherence
◇ Utilize individualized problem solving sessions to assist patient with their specific difficulties with using CPAP therapy. Troubleshoot problems early in treatment – within the first week.