Impact of CPAP on Activity Patterns and Diet in Patients with Obstructive Sleep Apnea (OSA)

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Study Objectives: Patients with severe OSA consume greater amounts of cholesterol, protein, and fat as well as have greater caloric expenditure. However, it is not known whether their activity levels or diet change after treatment with CPAP. To investigate this issue, serial assessments of activity and dietary intake were performed in the Apnea Positive Pressure Long-term Efficacy Study (APPLES); a 6-month randomized controlled study of CPAP vs. sham CPAP on neurocognitive outcomes.

Methods: Subjects were recruited into APPLES at 5 sites through clinic encounters or public advertisement. After undergoing a diagnostic polysomnogram, subjects were randomized to CPAP or sham if their AHI was ≥ 10 . Adherence was assessed using data cards from the devices. At the Tucson and Walla Walla sites, subjects were asked to complete validated activity and food frequency questionnaires at baseline and their 4-month visit.

Results: Activity and diet data were available at baseline and after 4 months treatment with CPAP or sham in up to 231 subjects (117 CPAP, 114 Sham). Mean age, AHI, BMI, and Epworth Sleepiness Score (ESS) for this cohort were 55 ± 13 [SD] years, 44 ± 27 /h, 33 ± 7.8 kg/m², and 10 ± 4 , respectively. The participants lacking activity and diet data

were younger, had lower AHI and arousal index, and had better sleep efficiency ($p < 0.05$). The BMI was higher among women in both CPAP and Sham groups. However, compared to women, men had higher AHI only in the CPAP group (50 vs. 34). Similarly, the arousal index was higher among men in CPAP group. Level of adherence defined as hours of device usage per night at 4 months was significantly higher among men in CPAP group (4.0 ± 2.9 vs. 2.6 ± 2.6). No changes in consumption of total calories, protein, carbohydrate or fat were noted after 4 months. Except for a modest increase in recreational activity in women (268 ± 85 vs. 170 ± 47 calories, $p < 0.05$), there also were no changes in activity patterns.

Conclusion: Except for a modest increase in recreational activity in women, OSA patients treated with CPAP do not substantially change their diet or physical activity habits after treatment.

Keywords: CPAP, physical activity, dietary patterns

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Obesity is considered a strong risk factor for the development and progression of obstructive sleep apnea (OSA).¹ Continuous positive airway pressure (CPAP) is considered the gold standard for OSA treatment and has been shown to improve daytime sleepiness, quality of life, and depressive symptoms, as well as reduce risk for cardiovascular disease and mortality.²⁻⁷ Despite these benefits, CPAP treatment is not considered curative and its success depends on compliance, which remains a major challenge.⁸ Thus, overweight patients are encouraged to lose weight with goal of reducing or eliminating the need for CPAP if sufficient weight loss is achieved. Moreover, there is the implied benefit that by alleviating fatigue and sleepiness, CPAP will lead to increased physical activity and promote weight loss. Unfortunately, several studies, including results from two randomized controlled trials, demonstrate that CPAP by itself does not engender weight loss and may actually promote weight gain.⁹⁻¹⁵

Changes in weight are a reflection of net caloric balance: the difference between caloric expenditures and consumption.

BRIEF SUMMARY

Current Knowledge/Study Rationale: Obesity is considered a strong risk factor for the development and progression of obstructive sleep apnea (OSA), and lifestyle modifications are encouraged in patients with OSA. However, it is unclear whether treatment with continuous positive airway pressure (CPAP) results in behavioral modifications. The purpose of this study was to assess the effect of CPAP on physical activity and dietary intake among patients with OSA.

Study Impact: Our findings suggest that OSA patients treated with CPAP do not substantially change their diet or physical activity habits. Additional interventions are required to modify diet and activity behavior in these patients.

However, there are few studies that have demonstrated the effect of OSA treatment on energy consumption and physical activity.^{16,17} Such information is vital, given that both obesity and OSA are independent risk factors for poor health and increased cardiovascular morbidity and mortality. Moreover, lifestyle modifications involving diet and physical activity are

encouraged in obese patients with OSA, but it is unclear whether treatment with CPAP results in behavioral modifications.

To study whether treatment of OSA with CPAP results in behavioral modification of physical activity and diet, an analysis was conducted using the data from a subset of the Apnea Positive Pressure Long-term Efficacy study (APPLES). Having previously observed a lack of weight loss in this cohort,⁹ we hypothesized that diet and physical activity patterns do not change with CPAP treatment.

METHODS

Study Population

APPLES is a multicenter, randomized, double-blinded, 2-arm, sham-controlled, intent to treat study of continuous positive airway pressure (CPAP) efficacy on neurocognitive function in OSA. A detailed description of the protocol has previously been published.¹⁴ Briefly, the participants were either recruited through local advertisement or from those attending sleep clinics for evaluation of possible OSA. Initial clinic evaluation included administering informed consent, screening questionnaires, history and physical examination, and a medical assessment by a study physician. The participants subsequently returned 2-4 weeks later for a 24-h sleep laboratory visit, during which polysomnography (PSG) was performed to confirm the diagnosis, followed by a day of neurocognitive and maintenance of wakefulness testing.

Inclusion have been published previously and included age ≥ 18 years and a clinical diagnosis of OSA, as defined by the American Academy of Sleep Medicine (AASM) criteria, and an apnea hypopnea index (AHI) ≥ 10 by polysomnography (PSG). Exclusion criteria included: previous CPAP use, oxygen desaturation on PSG $< 75\%$ for $> 10\%$ of the recording time, history of motor vehicle accident related to sleepiness, presence of chronic medical conditions, and the use of various medications known to affect sleep or neurocognitive function. Participants with AHI ≥ 10 were then randomized to CPAP or sham CPAP for continued participation in the APPLES study.

At 2 of the 5 clinical sites for APPLES, (The University of Arizona, Tucson, AZ and Providence St. Mary Medical Center, Walla Walla, WA), participants were recruited into a diet and physical activity sub-study. For this study, they were asked to complete questionnaires to assess their dietary and physical activity habits at their initial clinic evaluation, and then again at their 4-month clinic visit after starting CPAP or sham CPAP.

Assessment of Dietary Intake

Dietary intake was assessed using the computer administered VioFFQ,¹⁸ which is an electronic version of the Fred Hutchinson Cancer Research Center's (FHCRC) highly regarded Food Frequency Questionnaire (FFQ) used in the Women's Health Initiative (WHI). The FHCRC-FFQ is a reputable and validated tool with correlation coefficients for most nutrients ranging from 0.2-0.8 with a mean of 0.6.¹⁵ It contains items eaten over the past 3 months, along with the frequency and portion size of the item consumed. The FFQ is divided into 3 sections: (1) adjustment questions relating to food purchase and preparation; (2) questions regarding the frequency intake and portion size

of food and food groups; (3) summary questions regarding the intake of fruits and vegetables and the use of fat for cooking.^{19,20} The adjustment questions permit refined analysis of fat intake by asking food preparation practices. The summary questions are used to reduce the measurement bias of over-reporting food consumption when there are long lists of fruits and vegetables within food groups

Assessment of Physical Activity

The information on physical activity was gathered using the Arizona Activity Frequency Questionnaire (AAFQ). This instrument distinguishes between different types of physical activity, including recreational, household, and leisure activity. In addition to the caloric expenditure, it provides the amount of activity in metabolic equivalents or ratio of work metabolic rate to a standard metabolic rate (MET). One MET is roughly equivalent to the energy cost of sitting quietly or 0.0175 calories per minute per kilogram of body weight (Kcal/min/kg).¹⁶ This instrument has been validated using double-labeled water and has been shown to be effective in predicting total energy expenditure and physical activity energy expenditure in epidemiologic studies.^{17,18}

Polysomnography

The PSG montage included monitoring of the electroencephalogram (EEG, C₃-A₂ or C₄-A₁, O₂-A₁ or O₁-A₂), electrooculogram (EOG, ROC-A₁, LOC-A₂), chin and anterior tibialis electromyograms (EMG), heart rate by 2-lead electrocardiogram, snoring intensity (anterior neck microphone), nasal pressure (nasal cannula), nasal/oral thermistor, thoracic and abdominal movement (inductance plethysmography bands), and oxygen saturation (pulse oximetry). All PSG records were electronically transmitted to the data coordinating and PSG reading center. Sleep and wakefulness were scored using Rechtschaffen and Kales criteria.¹⁹ Apneas and hypopneas were scored using American Academy of Sleep Medicine Task Force (1999) diagnostic criteria.²⁰ Briefly, an apnea was defined by a clear decrease ($> 90\%$) from baseline in the amplitude of the nasal pressure or thermistor signal lasting ≥ 10 sec. Hypopneas were identified if there was a clear decrease ($> 50\%$ but $\leq 90\%$) from baseline in the amplitude of the nasal pressure or thermistor signal, or if there was a clear amplitude reduction of the nasal pressure signal ≥ 10 sec that did not reach the above criterion but was associated with either an oxygen desaturation $> 3\%$ or an arousal. Obstructive events were scored if there was persistence of chest or abdominal respiratory effort. Central events were noted if no displacement occurred on either the chest or abdominal channels.

Statistical Analysis

Data for continuous and interval variables were expressed as mean $\pm$ SD and for categorical variables as a percentage. Statistical analysis was performed using the STATA (Version 11, StataCorp TX USA).

Physical activity variables used in this analysis included total energy expenditure per day for recreational activities, leisure activities, and all other activities including household work and sleep. The dietary variables used were daily consumption of fruits, vegetables, carbohydrates, protein, fat, cholesterol,

Table 1—Baseline characteristics of APPLES participants

	All subjects randomized	Subjects with physical activity and nutrition data	After randomizing to treatment arms			
			SHAM		CPAP	
			Men	Women	Men	Women
N	1,105	231	74	40	80	37
Age, years (mean ± SD)	52 ± 12	55 ± 13	55 ± 14	54 ± 13	54 ± 13	55 ± 13
Gender, n (% men)	723 (65)	154 (67)	NA	NA	NA	NA
Ethnicity, n (% White)	841 (76)	189 (82)	58 (78)	33 (82)	68 (85)	30 (81)
BMI, kg/m ² (mean ± SD)	32 ± 7.2	33 ± 7.8	31 ± 5.5**	34 ± 8.8**	33 ± 6.3**	36 ± 11**
OSA severity, n (%)						
Mild	151 (14)	31 (13)	8 (11)	6 (15)	6 (7.5)	11 (30)
Moderate	344 (31)	59 (26)	23 (31)	12 (30)	17 (21)	7 (19)
Severe	607 (55)	141 (61)	43 (58)	22 (55)	57 (71)	19 (51)
AHI at baseline (mean ± SD)	40 ± 25	44 ± 27	42 ± 24	44 ± 31	50 ± 28**	34 ± 23**
ESS (mean ± SD)	10 ± 4.4	10 ± 4	9.7 ± 4.3	9.7 ± 3.7	10 ± 4	10.7 ± 4.6
Weight at baseline, kg (mean ± SD)	96 ± 23	98 ± 23	98 ± 17	91 ± 21	103 ± 21	97 ± 34
Weight at 6 months, kg (mean ± SD)	96 ± 23 [†]	98 ± 23 ^{††}	98 ± 17 [‡]	92 ± 22 [§]	103 ± 22 [‡]	97 ± 35 [§]
Total sleep time, min (mean ± SD)	376 ± 65	377 ± 71	387 ± 70	377 ± 62	376 ± 74	362 ± 73
Sleep efficiency, % (mean ± SD)	78 ± 13	77 ± 13	78 ± 13	77 ± 11	77 ± 14	74 ± 14
Sleep efficiency—6 months, % (mean ± SD)	81 ± 13	81 ± 13	80 ± 11	83 ± 14	82 ± 16	84 ± 6
Arousal index (mean ± SD)	29 ± 20	34 ± 22	33 ± 22	33 ± 22	38 ± 22**	29 ± 20**
CPAP adherence—4 months (mean ± SD)	NA	NA	2.6 ± 2.6*	2.9 ± 2.6	4.0 ± 2.9*	3.5 ± 2.8

BMI, body mass index; SD, standard deviation; OSA, obstructive sleep apnea; ESS, Epworth Sleepiness Scale; AHI, apnea hypopnea index; CPAP, continuous positive airway pressure. **p values < 0.05 (men vs. women). *p values < 0.05 (sham vs. PAP among men). The N for values of weight at 6 months differ from baseline; [†]812, ^{††}220. [‡]Men Sham 72, CPAP 72; [§]Women Sham 39, CPAP 37.

saturated fatty acids, trans fatty acids, fiber, and sucrose. After checking the normality of distribution, the Student paired *t*-test was used to compare the Sham and CPAP groups. Pearson correlation coefficient was computed to assess the relationship between sleep efficiency, total sleep time, and dietary and activity variables for the CPAP group. Linear regression models controlling for other potentially confounding factors (age, baseline body mass index [BMI, kg/m²], severity of OSA [AHI], sleepiness [Epworth Sleepiness Score (ESS)] and CPAP compliance [categorized as ≥ 4 h use per night or not]) were used to examine the association between treatment group and physical activity and dietary variables found to be statistically significant with paired *t*-testing. Sleep efficiency and total sleep time were included in the models if significant correlations were observed.

RESULTS

Table 1 demonstrates the demographic and other characteristics for all participants initially randomized in APPLES (n = 1,105), as well as those with and without information on physical activity and dietary data. The participants without information on physical activity and dietary habits were younger, slept better, and had a lower AHI.

After excluding those without physical activity and diet information at 4 months, there were 231 participants randomized to either treatment group (114 in Sham and 117 in CPAP) for this sub-study. Mean age among the participants of this sub-study was 55 years, 67% of participants were men, and majority of them were Caucasians (80%), with an average BMI of 33 kg/m².

A large proportion of the participants had severe OSA (61%), with an average AHI of 44/h, and PSG data demonstrating average sleep efficiency of 77% and total sleep time of 377 min.

After randomization, men were noted to have lower BMI in both groups (31 vs. 33 in Sham, and 34 vs. 36 in CPAP). In contrast, men in the CPAP group had significantly higher AHI (50 vs. 34; *p* < 0.05). Similarly, compared to women, men in the CPAP group had higher arousal index (38 vs. 29; *p* < 0.05).

Those randomized to CPAP, but not Sham, gained weight after 4 months; however, the results did not reach statistical significance. In addition, sleep efficiency after 6 months (per study design, PSG data were not recorded at 4 months) did not change significantly in either arm.

Table 2 and **Figures 1** and **2** describe the results from the paired *t*-tests displaying mean values of physical activity and diet variables stratified by gender and treatment group. With respect to physical activity, statistically significant differences were seen for energy expenditure related to recreational activities. For men, participants in the Sham group demonstrated decreased recreational activity related energy expenditure (*p* = 0.05) in comparison to men in the CPAP group. In contrast, women in the CPAP group exhibited increased recreational activity related energy expenditure in comparison to the Sham group (*p* = 0.05). There were no statistically significant differences in other energy expenditure variables among both men and women.

Similar to the finding related to recreational activities, as shown in **Table 2**, men in the Sham group decreased their fruit intake (*p* < 0.05). Among women, the intake of cholesterol, fat, saturated fatty acids, and protein were significantly decreased in the Sham

Table 2—Comparison of energy expenditure and nutrition between CPAP and sham stratified by gender

	Sham***			CPAP***		
	Baseline	4 Months	p value	Baseline	4 Months	p value
Men						
Energy Expenditure*	N = 58			N = 59		
Total Calories	3079 ± 90	2992 ± 73	0.27	3119 ± 93	3176 ± 98	0.28
Recreational Calories	378 ± 64	275 ± 41	0.05	321 ± 55	314 ± 55	0.85
Leisure Calories	835 ± 49	818 ± 37	0.67	788 ± 49	780 ± 45	0.88
Household Calories	578 ± 39	637 ± 49	0.21	541 ± 46	587 ± 52	0.29
Other Calories	119 ± 36	138 ± 45	0.62	86 ± 27	119 ± 43	0.31
Nutrition**	N = 74			N = 80		
Fruit	2.1 ± 0.19	1.8 ± 0.17	0.02	1.87 ± 0.15	1.83 ± 0.16	0.72
Vegetable	2.25 ± 0.18	2.5 ± 0.23	0.22	2.95 ± 0.22	2.94 ± 0.22	0.95
Carbohydrates	221 ± 12	218 ± 13	0.76	251 ± 14	241 ± 14	0.32
Cholesterol	329 ± 21	318 ± 26	0.55	381 ± 27	374 ± 30	0.8
Fat	91 ± 5.3	86 ± 6.8	0.32	99 ± 6.1	96 ± 5.8	0.61
Saturated fatty acids	31.5 ± 1.9	29 ± 2.4	0.29	33 ± 2.2	33 ± 2.3	0.94
Trans fatty Acids	4.5 ± 0.28	4.6 ± 0.42	0.71	5.2 ± 0.39	4.9 ± 0.37	0.3
Fiber	18 ± 1.0	18.5 ± 1.2	0.47	19.4 ± 1.1	19.4 ± 1.1	0.98
Protein	84 ± 3.7	83 ± 5	0.72	97 ± 5.6	95 ± 5	0.59
Sucrose	43 ± 3.7	40 ± 3.7	0.45	43 ± 2.9	40 ± 2.9	0.37
Women						
Energy Expenditure*	N = 36			N = 31		
Total Calories	2374 ± 77	2350 ± 124	0.83	2340 ± 95	2452 ± 118	0.16
Recreational Calories	152 ± 37	170 ± 47	0.66	111 ± 23	268 ± 85	0.05
Leisure Calories	616 ± 45	629 ± 43	0.78	600 ± 49	562 ± 44	0.38
Household Calories	509 ± 49	526 ± 55	0.71	648 ± 68	645 ± 74	0.97
Other Calories	59 ± 26	47 ± 28	0.67	64 ± 35	20 ± 10	0.23
Nutrition**	N = 39			N = 37		
Fruit	1.8 ± 0.25	1.95 ± 0.27	0.57	2.2 ± 0.36	2.1 ± 0.29	0.83
Vegetable	3.1 ± 0.33	2.8 ± 0.28	0.34	3.4 ± 0.36	3.0 ± 0.29	0.1
Carbohydrates	220 ± 19	188 ± 14	0.09	193 ± 15	176 ± 12	0.11
Cholesterol	337 ± 38	252 ± 24	0.005	265 ± 32	226 ± 25	0.11
Fat	90 ± 8.9	69 ± 6	0.001	76 ± 7.9	68 ± 6.6	0.08
Saturated fatty acids	30 ± 3.1	24 ± 2.5	0.003	25 ± 2.7	22 ± 2.3	0.1
Trans fatty Acids	4.7 ± 0.61	3.5 ± 0.33	0.008	4.1 ± 0.54	2.9 ± 0.39	0.002
Fiber	19.6 ± 1.7	16.6 ± 1.3	0.06	18.2 ± 1.3	17.6 ± 1.2	0.54
Protein	86 ± 6.7	71 ± 6.1	0.008	75 ± 5.7	69 ± 4.9	0.17
Sucrose	37 ± 4.2	33 ± 3.7	0.38	36 ± 3.4	34 ± 2.8	0.53

*Adjusted energy expenditure (kilojoules/day). **Values (mean ± SD) are grams except for fruits/vegetables (servings). ***p values are given for comparisons between baseline and 4 months and statistically significant values are bolded.

group ($p < 0.05$). However, the trans fatty acid intake was significantly decreased in both the Sham and CPAP groups ($p < 0.05$).

Among the CPAP group, the correlation coefficient analysis demonstrated significant positive correlation between total sleep time and household calories expenditure among men ($r = 0.27$, $p < 0.05$). Similarly positive correlation was noted between sleep efficiency and household ($r = 0.27$, $p < 0.05$) and total caloric ($r = 0.28$, $p < 0.05$) expenditure in men. In contrast strong negative correlation was noted between sleep efficiency and household caloric expenditure ($r = -0.40$, $p < 0.05$) among women. In addition, negative correlation was noted between fat intake and sleep efficiency ($r = -0.34$, $p < 0.05$) among women. No other significant correlations were found.

Table 3 displays the fully adjusted regression models for recreational, household, and total calories, as well as fat,

saturated fat, and trans fatty acids stratified by gender. Almost all of the univariate associations between physical activity and dietary intake and treatment group were no longer statistically significant after controlling for age, baseline BMI, ESS and AHI, CPAP compliance, total sleep time, and sleep efficiency. However, the finding that treatment with CPAP significantly increased the recreational activities only among women remained significant ($R^2 = 0.22$, $p < 0.05$). Interestingly strong negative association was found between total sleep time and saturated fat intake among men ($p < 0.05$).

DISCUSSION

Obesity is widely known to be associated with OSA, and weight loss advice generally is included in the treatment plan.

Figure 1

(A) Change in energy expenditure among men stratified by treatment group (Sham vs. CPAP) at baseline and at 4 months. The variables include total energy expenditure per day for recreational (rec.) activities, leisure activities, household activities, and all other activities. Values are adjusted energy expenditure measured in kilojoules per day. (B) Change in energy expenditure among women stratified by treatment group (Sham vs. CPAP) at baseline and at 4 months. The variables include total energy expenditure per day for recreational activities, leisure activities, household activities, and all other activities. Values are adjusted energy expenditure measured in kilojoules per day. * $p < 0.05$.

Figure 2

(A) Change in dietary habits among men stratified by treatment group (Sham vs. CPAP) at baseline and at 4 months. The variables include consumption of carbohydrates (carbs), cholesterol, fats, saturated fats, and proteins. Values are grams per day. (B) Change in dietary habits among women stratified by treatment group (Sham vs. CPAP) at baseline and at 4 months. The variables include consumption of carbohydrates, cholesterol, fats, saturated fats, and proteins. * $p < 0.05$.

In this study we prospectively examined the link between CPAP use and change in lifestyle. As hypothesized, treatment with CPAP had little impact on physical activity or dietary habits. The results were independent of several potential confounders including ESS, AHI, total sleep time, sleep efficiency, CPAP adherence, age, and BMI.

To our knowledge, this is the first study evaluating gender differences and effects of CPAP treatment on lifestyle. Overall,

no significant improvement in physical activity was noted; however, after stratifying for gender, we demonstrated a marginally significant increase in recreational activity levels among women with CPAP therapy. On the contrary, in a multiple regression model, there was no significant impact of CPAP on recreational activity among men. Interestingly, there was a statistically significant, but perhaps marginal decline in recreational activity among men in the Sham group. The explanation

Table 3—Multiple regression model stratified by gender

	Recreational Calories Beta (95% CI)	Household Calories Beta (95% CI)	Total Calories Beta (95% CI)	Fat Beta (95% CI)	Trans Fatty Acids Beta (95% CI)	Saturated Fats Beta (95% CI)
Men						
CPAP	59 (-82 to 200)	-0.44 (-187 to 99)	-0.54 (-1.4 to 0.4)	2.0 (-13 to 17)	-0.54 (-1.5 to 0.4)	1.5 (-4.3 to 7.4)
Age	-2.3 (-9.2 to 4.6)	3.2 (-3.9 to 10)	-0.02 (-0.06 to 0.02)	-0.03 (-0.6 to 0.7)	-0.02 (-0.06 to 0.02)	-0.03 (-0.23 to 0.28)
BMI, kg/m ²	-3.6 (-18 to 11)	-3.8 (-19 to 11)	0.002 (-0.1 to 0.1)	-0.73 (-2.2 to 0.72)	0.002 (-0.09 to 0.09)	0.23 (-0.79 to 0.34)
AHI	0.5 (-2.5 to 3.5)	1.4 (-1.6 to 4.5)	-0.01 (-0.03 to 0.01)	0.06 (-0.26 to 0.39)	-0.005 (-0.02 to 0.02)	0.04 (-0.09 to 0.17)
ESS	3.9 (-14 to 22)	5.4 (-13 to 23)	-0.01 (-0.1 to 0.1)	-0.17 (-2 to 1.6)	-0.01 (-0.12 to 0.11)	-0.01 (-0.71 to 0.69)
Compliance	84 (-69 to 236)	-83 (-238 to 73)	0.11 (-0.9 to 1.1)	-1.8 (-17 to 14)	0.11 (-0.9 to 1.1)	-0.40 (-6.5 to 5.7)
Total sleep time	-0.16 (-2.3 to 2.0)	-0.4 (-2.6 to 1.8)	-0.01 (-0.03 to 0.004)	-0.22 (-0.48 to 0.03)	-0.01 (-0.03 to 0.004)	-0.10 (-0.20 to -0.004)*
Sleep efficiency	2.8 (-9.9 to 15)	5.8 (-7.1 to 18)	0.05 (-0.04 to 0.15)	-0.99 (-0.46 to 2.4)	0.05 (-0.4 to 0.15)	-0.50 (-0.06 to 1.1)
Women						
CPAP	227 (48 to 405)*	-77 (-221 to 68)	0.44 (-1.5 to 0.6)	6.2 (-10 to 22)	-0.45 (-1.5 to 0.6)	1.4 (-3.9 to 6.7)
Age	-3.7 (-12 to 4.9)	-3.7 (-11 to 3.3)	-0.04 (-0.01 to 0.1)	0.72 (-0.07 to 1.5)	0.04 (-0.02 to 0.01)	0.30 (0.04 to 0.56)*
BMI, kg/m ²	-6.7 (-19 to 5.4)	3.8 (-0.6 to 14)	-0.02 (-0.1 to 0.05)	0.62 (-0.45 to 1.7)	-0.02 (-0.09 to 0.05)	0.27 (-0.08 to 0.61)
AHI	2.9 (-0.7 to 6.6)	-1.1 (-4.1 to 1.8)	-0.02 (-0.04 to 0.01)	-0.24 (-0.57 to 0.09)	-0.02 (-0.04 to 0.01)	-0.09 (-0.2 to 0.01)
ESS	-36 (-58 to -13)*	12 (-5.7 to 30)	0.1 (-0.02 to 0.2)	1.8 (-0.14 to 3.7)	0.1 (-0.02 to 0.2)	0.58 (-0.05 to 1.2)
Compliance	17 (-157 to 192)	154 (12.8 to 296)*	0.62 (-0.4 to 1.6)	5.0 (-11 to 21)	0.62 (-0.4 to 1.7)	1.9 (-3.5 to 7.2)
Total sleep time	0.76 (-1.9 to 3.4)	-2.2 (-4.4 to -0.08)*	-0.004 (-0.02 to 0.01)	0.03 (-0.2 to 0.3)	-0.004 (-0.02 to 0.01)	0.01 (-0.07 to 0.1)
Sleep efficiency	-5.8 (-20 to 9.0)	10 (-1.9 to 22)	-0.01 (-0.09 to 0.08)	-0.04 (-1.4 to 1.3)	-0.01 (-0.09 to 0.08)	0.03 (-0.5 to 0.4)

BMI, body mass index; SD, standard deviation; OSA, obstructive sleep apnea; ESS, Epworth Sleepiness Scale; AHI, apnea hypopnea index; CPAP, continuous positive airway pressure. The beta coefficient in a regression model ($Y = a + b_1X_1 + b_2X_2 + b_3X_3 \dots$) is a measure of how strongly each predictor variable influences the dependent variable. In such models, Y is the dependent variable, a is the intercept with the Y axis, b_1 is beta coefficient for X_1 (1st independent variable), b_2 is the beta coefficient for X_2 (2nd independent variable), b_3 is the beta coefficient for X_3 (3rd independent variable), etc. For example in Table 3 above, Recreational Calories is the dependent variable in the 2nd column, and for women, the beta coefficient for CPAP use is 227 and ESS is -36 with the 95% confidence intervals of the beta coefficient shown in parentheses. Both are statistically significant. The other beta coefficients are not. *p values < 0.05.

for this finding is unclear. However, the Sham group's baseline value was relatively high in comparison to the CPAP group, and this may represent a regression to the mean. Although we observed several significant correlations between sleep efficiency and total sleep time and a few physical activity and dietary variables, a significant relationship was noted between total sleep time and saturated fat intake only among men.

The results of this study are in line with those of previous research on this topic. West et al.¹⁷ failed to display improvement in activity level among 36 men who completed one week of actigraphy before and after CPAP or Sham. There was no significant difference in the level of activity at baseline between the two groups, and the activity levels did not significantly change in either group after CPAP or Sham. However, the study did not include women, and the duration of the study was short. Similarly, another study (n = 41; 35 men and 6 women), prospectively examined the influence of CPAP therapy on physical activity among OSA patients. The study used an accelerometer to measure energy expenditure in METS and kilocalories, mean number of steps per day, lying time in hours per day, and activity duration in minutes per day during pre- and post-CPAP treatment period. However, no significant improvement in any of the physical activity parameters was found after a mean follow-up of 9 months.¹⁶ Despite the fact that CPAP treatment improved daytime symptoms, there was no apparent explanation for this lack of improvement in physical activity level. Stenlof et al.²¹ have demonstrated improvement in nocturnal energy expenditure among patients with sleep apnea.

However, no change in basal metabolic rate was noted after CPAP treatment. Similarly, another study failed to find a difference in basal metabolic rate in patients with severe sleep apnea and controls.²² Our study extends these previous findings to a larger cohort with a Sham CPAP control group.

Although it is unclear why men in our study using CPAP did not change their physical activity patterns, several explanations are possible. First, severe obesity as observed in many persons with OSA, by itself may be a limiting factor to increasing physical activity. Second, improvement in OSA by CPAP may not be sufficient to change habitual patterns of physical inactivity without additional interventions. Third, poor CPAP adherence found in our cohort could potentially account for this lack of improvement in physical activity. Despite these disappointing findings in men, women did appear to modestly increase their recreational activity, thus underscoring differences between genders in determining behavior change.

In univariate analyses, we found that men with OSA do not change their dietary habits after treatment with CPAP. In contrast, women were noted to have healthier eating habits in both groups, particularly among those receiving Sham CPAP. Nevertheless, for both men and women, multivariate analysis failed to detect any impact of CPAP on change in dietary habits. Another large, prospective, controlled study examining the long-term effects of CPAP did not find any significant change in alcohol and coffee intake during the course of the study.²³ However, other dietary habits and caloric intake were not assessed. In a previous cross-sectional analysis of these APPLES

participants, Vasquez et al. demonstrated higher consumption of diet rich in cholesterol, protein, total fat, and total saturated fatty acids by subjects with severe sleep disordered breathing compared to those with less severe SDB.²⁴ Our smaller subset of this original cohort extends these results by showing little long-term change in dietary behavior. There are several mechanisms that might influence dietary habits in persons with OSA. Although persons with OSA usually do not have a reduction in total sleep time, alteration in neuroendocrine control of feeding behavior has been suggested with sleep deprivation.²⁵ Moreover, change in eating behavior favoring non homeostatic food intake has also been reported with sleep deprivation.²⁶ Furthermore, eating to maintain wakefulness may be occurring. Irrespective of the factors determining dietary behavior in OSA patients, our findings are important because they highlight the need for interventions in addition to treatment with CPAP to change eating behavior in OSA.

Despite its strengths, the current study has some limitations that deserve comments. The main limitation of this study is the use of questionnaire for acquiring data. The food frequency questionnaire used in this study is widely used to document food intake in research studies. However, reporting biases related to these questionnaires include perception of portion size, and tendency of some participants to respond inaccurately based on their perceived appropriateness. We acknowledge that our results may have differed if all the participants had undergone rigorous nutritional assessment. Similarly, energy expenditure may not be accurately measured in physical activity questionnaires. Although use of questionnaires for data acquisition is not ideal, more precise assessments of physical activity and diet are not feasible in large randomized controlled trials or longitudinal cohort studies. Additionally, our adherence to CPAP was only approximately 4 hours per night; it is possible that change in dietary and physical activity patterns would have been observed if compliance was higher. However, CPAP compliance was not a significant factor in our final models making this explanation less likely. Finally, since the majority of patients with OSA are obese, a 4-month period might not be ideal for change in lifestyle. Despite these limitations, the strengths of the study include a large number of participants, a randomized Sham CPAP control group, and documentation of CPAP compliance.

In conclusion, routine use of CPAP is unlikely to result in substantial behavioral modifications of physical activity and dietary habits. Future studies are needed to understand the association between CPAP treatment and lack of improvement in lifestyle, particularly with respect to gender differences.

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