Longitudinal Evaluation of Sleep-Disordered Breathing and Sleep Symptoms with Change in Quality of Life: The Sleep Heart Health Study (SHHS)

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Study Objectives: Findings from population studies evaluating the progression and incidence of sleep disordered breathing have shown evidence of a longitudinal increase in the severity of sleep disordered breathing. The present study evaluates the association among changes in sleep disordered breathing, sleep symptoms, and quality of life over time.

Design: Prospective cohort study. Data were from the Sleep Heart Health Study.

Setting: Multicenter study.

Participants: Three thousand seventy-eight subjects aged 40 years and older from the baseline and follow-up examination cycles were included.

Measurements: The primary outcomes were changes in the Physical Component Summary and Mental Component Summary scales obtained from the Medical Outcomes Study Short-Form Health Survey. The primary exposure was change in the respiratory disturbance index obtained from unattended overnight polysomnograms performed approximately 5 years apart. Other covariates included measures of excessive daytime sleepiness and difficulty initiating and maintaining sleep.

Results: Mean respiratory disturbance index increased from 8.1 ± 11 SD at baseline to 10.9 ± 14 ($P < 0.0001$) at follow-up. The mean Physical Component Summary and Mental Component Summary scores were 48.5 and 54.1 at baseline and 46.3 and 54.8 at follow-up. No associations between change in respiratory disturbance index and changes in Physical Component Summary or Mental Component Summary scores were seen. However, worsening of difficulty initiating and maintaining sleep and excessive daytime sleepiness were significantly associated with lower quality of life.

Conclusions: A slight increase in severity of sleep disordered breathing was seen over 5 years; this was not associated with worsening of quality of life. However, subjective symptoms of quality of sleep and daytime sleepiness were associated with declining quality of life.

Keywords: Sleep disordered breathing, quality of life, longitudinal, quality of sleep, excessive daytime sleepiness

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SLEEP DISORDERED BREATHING (SDB) IS A COMMON DISORDER THAT AFFECTS 2% TO 4% OF THE ADULT POPULATION.[1] SDB HAS BEEN ASSOCIATED WITH A wide range of morbidities, including obesity, hypertension, cardiovascular disease, and diabetes.[2,3] Many patients with SDB experience excessive daytime sleepiness (EDS),[4] considered to be the chief symptom responsive to SDB treatment. EDS, occurring secondary to SDB or to other factors, affects approximately 12% of the population[5] and has been associated with poor cognitive performance,[6] proneness to accidents,[7] and poorer health-related quality of life.[8]

Cross-sectional associations between SDB and reduced quality of life have been shown in several patient and community studies.[9,10] Results from clinic-based investigations[11] have shown higher associations than those from population-based samples.[12] Other studies have focused on evaluating quality of life after treatment for SDB, some of which have shown significant improvement in well being after treatment with continuous positive airway pressure.[13] Although several studies have shown longitudinal progression of SDB,[14,15] no study has yet evaluated the associations between changes in SDB and quality of life over time.

The present study assessed the associations among changes in SDB, sleep quality, daytime sleepiness, and health-related quality of life in participants from a multiethnic cohort study. We hypothesized that increases in severity of SDB and worsening of sleep symptoms would be associated with a decrease in quality of life.

METHODS

The Sleep Heart Health Study (SHHS) is a prospective multicenter cohort study designed to investigate the relationship between SDB and cardiovascular diseases in the United States. Details of the study design have been published elsewhere.[16] Briefly, initial baseline recruitment began in 1995, enrolling 6441 subjects, 40 years of age and older, from several ongoing geographically distinct cardiovascular and respiratory disease cohorts that were initially assembled between 1976 and 1995.[17] These cohorts included the Offspring Cohort and the Omni Cohort of the Framingham Heart Study in Massachusetts; the Hagerstown, MD, and Minneapolis, MN, sites of the Athero-

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sclerosis Risk in Communities Study; the Hagerstown, MD, Pittsburgh, PA, and Sacramento, CA, sites of the Cardiovascular Health Study; 3 hypertension cohorts (Clinic, Worksite, and Menopause) in New York City; the Tucson Epidemiologic Study of Airways Obstructive Diseases and the Health and Environment Study; and the Strong Heart Study of American Indians in Oklahoma, Arizona, North Dakota, and South Dakota. A 5-year SHHS follow-up examination took place between February 2000 and May 2003, enrolling 4586 of the original participants who had a repeat polysomnogram, in addition to completing questionnaires and undergoing other measurements. The present study focused on 3078 subjects who had polysomnograms at baseline and follow-up. Data for all 215 follow-up participants from the New York City site were excluded from these analyses because they did not meet polysomnography-study data-quality standards.[18] The SHHS was approved by the respective institutional review boards for human subjects research, and informed written consent was obtained from all subjects at the time of their enrollment into each stage of the study.

Sleep Habits Questionnaire and Covariates

During the baseline and follow-up studies, all participants completed the SHHS Sleep Habits Questionnaire.[19] The Sleep Habits Questionnaire contained questions regarding sleep habits and smoking status, as well as cardiovascular disease and respiratory problems. Subjects were classified as having coronary heart disease (CHD) if they answered *yes* to having a physician ever telling them they had any of the following: angina, heart attack, stroke, or heart failure or ever having had any of the following procedures: coronary artery bypass surgery, coronary angioplasty, insertion of a pacemaker, or any other cardiac operation. Subjects were classified as having chronic respiratory disease if they answered *yes* to having a doctor tell them that they had emphysema, chronic bronchitis, chronic obstructive pulmonary disease, or asthma and if the asthma was still present (participants reported having had an asthma attack in the last 12 months). Height and weight were measured directly to determine body mass index (BMI, kg/m^2). Sex, ethnicity, education, and marital status were derived from data obtained from the SHHS parent cohorts. Use of sleeping medications was recorded on the night of each polysomnogram.

Polysomnography

Baseline and follow-up SHHS participants underwent overnight in-home polysomnograms using the Compumedics Portable PS-2 System (Abbottsville, Victoria, Australia) administered by trained technicians. The methods for obtaining polysomnography data were the same for the baseline and follow-up examination cycles.[20] Briefly, after a home visit was scheduled, the Sleep Health Questionnaires generally were mailed 1 to 2 weeks prior to the in-home polysomnography appointment. Each participant was asked to complete the questionnaire prior to the home visit, at which time the Sleep Health Questionnaire was collected and verified for completeness. The home visits were performed by 2-person mixed-sex teams in visits that lasted 1.5 to 2 hours. There was emphasis on making the night of the polysomnographic assessment as representative as possible of a usual night of sleep. Participants were asked to schedule the visit so that it would occur approximately 2 hours prior to their usual bedtime. Participants' weekday or weekend bedtime routines were encouraged to be consistent with the day of the week the visits were made.

The SHHS recording montage consisted of electroencephalogram (C_4/A_1 and C_3/A_2), right and left electrooculogram, a bipolar submental electromyogram, thoracic and abdominal excursions (inductive plethysmography bands), airflow (detected by a nasal-oral thermocouple [Protec, Woodinville, WA]), oximetry (finger pulse oximetry [Nonin, Minneapolis, MN]), electrocardiogram and heart rate (using a bipolar electrocardiogram lead), body position (using a mercury gauge sensor), and ambient light (on/off, by a light sensor secured to the recording garment). Sensors were placed, and equipment was calibrated during an evening home visit by a certified technician. After technicians retrieved the equipment, the data, stored in real time on PCMCIA cards, were downloaded to the computers of each respective clinical site, locally reviewed, and forwarded to a central reading center (Case Western Reserve University, Cleveland, OH). Comprehensive descriptions of polysomnography scoring and quality-assurance procedures have been previously published.[20,21] In brief, sleep was scored according to guidelines developed by Rechtschaffen and Kales.[22] Strict protocols were maintained to ensure comparability among centers and technicians. Intrascorer and interscorer reliability was high.[21] As in previous analyses of SHHS data, an apnea was defined as a complete or almost complete cessation of airflow, as measured by the amplitude of the thermocouple signal, lasting at least 10 seconds. Hypopneas were identified if the amplitude of a measure of flow or volume (detected by the thermocouple or thorax or abdominal inductance band signals) was discernibly reduced (at least 25% lower than baseline breathing) for at least 10 seconds but did not meet the criteria for apnea. For this study, only apneas or hypopneas associated with a 4% or greater oxyhemoglobin desaturation were considered in the calculation of the respiratory disturbance index (RDI, apneas + hypopneas per hour of total sleep time).

Sleepiness and Quality of Life Measures

The level of daytime sleepiness was determined using the Epworth Sleepiness Scale (ESS), a validated 8-item questionnaire that measures subjective sleepiness.[23] Subjects were asked to rate how likely they are to fall asleep in different situations. Each question was answered on a scale of 0 to 3. ESS values ranged from 0 (unlikely to fall asleep in any situation) to 24 (high chance of falling asleep in all 8 situations).

Mean ESS scores between 14 and 16 have been reported for patients with SDB.[23,24] Scores of 11 or greater are considered to represent an abnormal degree of daytime sleepiness.[25] Sleepiness was defined as an ESS of at least 11. Difficulty initiating and maintaining sleep (DIMS) or insomnia was assessed using the following questions from the Sleep Health Questionnaire: *Do you have trouble falling asleep?; Do you wake up during the night and have difficulty getting back to sleep?;* and, *Do you wake up too early in the morning and are unable to get back to sleep?* Answers ranged from "Never" to "Almost Always" on a 5-point Likert-like scale. DIMS was dichotomized into a no/

yes variable, with DIMS considered to be present if the participant answered "Often" or "Almost Always" to any of these questions.

Quality of life was evaluated using the Medical Outcomes Study Short-Form Health survey (SF-36).[26] The SF-36 is a multipurpose self-administered health survey consisting of 36 questions divided into 8 individual domains: (1) physical functioning (limitations in physical activity because of health problems), (2) role physical (limitations in usual role activities because of physical health problems), (3) bodily pain, (4) general health perceptions; (5) vitality (energy and fatigue), (6) social functioning (limitation in social activities because of physical or emotional problems), (7) role emotional (limitation in usual role activities because of emotional problems), and (8) general mental health. In addition, the 8 scales are used to form 2 distinct high-order summary scales: the physical component summary (PCS) and the mental component summary (MCS).[27] The PCS includes the physical functioning, role physical, bodily pain, and general health scales, and the MCS includes the vitality, social functioning, role emotional, and general mental health scales. The raw scores for each subscale and the 2 summary measures are standardized, weighted, and scored according to specific algorithms. The scores for the multifunction item scales and the summary measures range from 0 to 100, with higher scores indicating better quality of life.

Statistics

The ethnic group distribution included 75% Caucasian, 14% Native American, 6% African American, 4% Hispanic/Mexican American, and 1% Asian or Pacific Islander. This variable was dichotomized into Caucasians and other ethnic groups for analyses in regression models. Smoking was assessed at baseline and follow-up and categorized into never, current, and exsmoking according to the participant's report. Education was categorized into persons with less than 9, 9 to 12, more than 12 to 16, and more than 16 years of education. BMI was divided into nonobese (< 30 kg/m^2) and obese (≥ 30 kg/m^2) groups, according to established clinical guidelines.[28] CHD and respiratory diseases were dichotomized into no/yes variables. Sleeping pill usage was dichotomized into no/yes, with yes including subjects who consumed any amount of sleeping pills. RDI was categorized into the following groups: 5 or fewer, more than 5 to 15 or fewer, more than 15 to fewer than 30, and 30 or more events per hour of total sleep time. BMI and RDI were used as categorical variables to assess proportions in descriptive analyses and were used as continuous variables in the regression models. χ^2 tests were used to test differences in proportions, and *t*-tests and analyses of variance were used to compare differences in mean values. Changes over time for time-varying exposure variables were determined as follow-up minus baseline levels. The values for MCS and PCS were negative if decline was seen during the follow-up. Positive values for RDI, DIMS, and ESS of 11 or greater indicated worsening from baseline to follow-up.

Separate unadjusted and adjusted multiple linear regression models were fitted to estimate the effect of change in RDI, ESS, and DIMS as independent variables on changes in MCS and PCS as the 2 dependent variables. The multiple regression models included change and baseline values for age, BMI, smoking status, sleeping pill use, and total sleep time on polysomnography. Baseline CHD and respiratory diseases were also included as potential confounding factors. Exploratory models were also adjusted for sex, ethnicity, marital status, and education level. However, these additional variables were not significant in any of the models, and only sex was retained. Variables included in the models were selected in accordance to possible biologic associations or in accordance to previously published studies. Statistical analyses were conducted using Intercooled Stata version 9.0 statistical software (Stata Corp, College Station, TX). A significance level of $P < 0.05$ was used for all statistical tests.

RESULTS

The mean age was 62.0 years at baseline and 67.3 years at follow-up (data not shown). Overall, 55% were women, most were Caucasian (75%), and the majority of the sample was married (77%) (Table 1). In general, current smoking decreased from 12% to 9% between baseline and follow-up. The mean BMI increased slightly from 28.7 to 29.3 from baseline to follow-up, with the percentage of obese subjects (BMI ≥ 30) increasing from 35% to 38%. The percentage of subjects with CHD increased from 15% at baseline to 20% at follow-up, and the percentage with respiratory disease increased from 9% to 12%. A higher proportion of men had CHD, whereas women had higher rates of respiratory diseases at both surveys. The proportion of participants who took sleeping pills increased from 20% to 24%, with a greater percentage of women taking pills, compared with men, at both surveys. Polysomnography total sleep time increased slightly from baseline (364 ± 60 minutes) to follow-up (368 ± 70 minutes), with women showing higher polysomnography total sleep time than man. Although mean RDI increased from baseline (8.1 ± 11) to follow-up (10.9 ± 14), the percentage of subjects with an ESS score of 11 or greater decreased from baseline to follow-up (25% to 22%). A higher percentage of women reported DIMS, whereas a higher percentage of men were observed with an ESS score of 11 or greater. Mean PCS decreased from baseline to follow-up (48.5 ± 9 to 46.3 ± 10), whereas mean MCS increased only slightly (54.1 ± 8 to 54.8 ± 8).

Baseline and Follow-up differences in PCS and MCS

Significantly lower scores for women than men were seen at baseline and follow-up for the PCS and MCS (Table 2). Hispanics or Mexican Americans had lower MCS and PCS scores compared with the other ethnic groups only at baseline. There were no differences in PCS scores between current smokers and exsmoker or those who had never smoked; however, current smokers had significantly lower MCS scores during both surveys. PCS and MCS scores varied by marital status, but no particular trends were noted. At both surveys, with the exception of MCS at follow-up, more highly educated subjects reported higher scores for PCS and MCS, as compared with those who had obtained less education. Obese subjects had lower PCS scores than did nonobese subjects at baseline and follow-up; however, no difference was found for MCS at either survey. Scores for both summary scales were lower for subjects with respiratory diseases and those taking sleeping pills, whereas

Table 1—Descriptive Characteristics by Sex for Baseline and Follow-up Values

Charateristic	Baseline (n = 3078)			Follow-up (n = 3078)		
	Women	Men	Overall	Women	Men	Overall
Women, %			55			
Ethnicity[δ], %						
White	73	79	75			
Black	6	5	6			
Native American/Alaskan	16	11	14			
Asian/Pacific Islander	1	2	1			
Hispanic/Mexican American	4	3	4			
Marital Status[δ], %						
Married	68	87	77			
Widowed	15	2	9			
Divorced/separated	13	8	10			
Never married	4	3[‡]	4			
Education, years[δ], %						
< 9	5	6	6			
9-12	44	34	40			
13-16	30	30	29			
> 16	21	30[‡]	25			
Age, y[*]	61.9 ± 10	62.3 ± 10	62.0 ± 10	67.9 ± 11	68.3 ± 10	67.3 ± 10
Smoking[†] (%)						
Exsmoker	55	35	46	58	39	49
Current	11	12	12	9	9	9
Never	34	53[‡]	42	33	52[‡]	41
BMI continuous (Mean ± SD)[*]	28.8 ± 5.9	28.7 ± 4	28.7 ± 5	29.3 ± 6	29.2 ± 5	29.3 ± 6
BMI[†] (%)						
< 30	64	65	65	61	62	62
≥ 30	36	35	35	39	38	38
Chronic Heart Disease[†] (%)						
Yes	11	19	15	15	26	20
No	86	81[‡]	85	84	74[‡]	80
Respiratory Disease[†] (%)						
Yes	11	7	9	14	10	12
No	89	93[‡]	91	86	90[‡]	88
Takes Sleeping Pills[†] (%)						
Yes	25	14	20	29	18	24
No	75	86[‡]	80	71	82[‡]	76
TST (Mean ± SD)[§]	371 ± 62	355 ± 57[£]	364 ± 60	384 ± 71	358 ± 69[£]	368 ± 70
RDI continuous (Mean ± SD)[*]	6.2 ± 9	10.5 ± 12[£]	8.1 ± 11	8.4 ± 11	13.9 ± 15[£]	10.9 ± 14
RDI[†] (%)						
< 5	64	43	54	52	34	44
5 - < 15	25	35	29	32	34	33
15 - < 30	8	15	11	11	19	15
≥ 30	3	7[‡]	5	5	13[‡]	8
DIMS[†] (%)						
Yes	33	25	29	33	28	30
No	67	75[‡]	71	67	72[‡]	70
ESS ≥ 11[†] (%)						
Yes	21	29	25	18	26	22
No	79	71[‡]	75	82	74[‡]	78
PCS (Mean ± SD)[*]	47.9 ± 10	49.2 ± 9[£]	48.5 ± 9	45.5 ± 11	47.3 ± 10[£]	46.3 ± 10
MCS (Mean ± SD)[*]	52.8 ± 9	53.8 ± 8[£]	54.1 ± 8	54.2 ± 8	54.9 ± 8[**]	54.8 ± 8

Data are presented as mean ± SD or percentage, unless otherwise indicated. [δ]Measured at baseline. [£]$P < 0.0001$ for *t*-test by sex. [‡]$P < 0.0001$ for χ^2 test by sex. [*]$P < 0.0001$ and [§]$p < 0.05$ for paired *t*-test between baseline and follow-up. [†]$P < 0.001$ for χ^2 test between baseline and follow-up. [**]$P < 0.05$ for *t*-test by sex.

PCS but not MCS scores were significantly lower for subjects with CHD. Subjects in the higher categories of RDI had lower mean scores for PCS, but no trend was seen for MCS at baseline or follow-up. PCS and MCS scores were significantly lower for subjects who reported having DIMS or an ESS score of 11 or greater during both surveys.

Table 2—PCS and MCS by Descriptive Variables for Baseline and Follow-up Values

	Baseline		Follow-up	
	PCS	**MCS**	**PCS**	**MCS**
Female	48 ± 10	54 ± 8	46 ± 11	54 ± 8
Male	49 ± 9*	55 ± 7§	47 ± 10*	55 ± 7
Ethnicity				
White	49 ± 9	54 ± 7	46 ± 10	55 ± 8
Black	47 ± 10	53 ± 10	45 ± 10	55 ± 8
Native American or Alaskan	52 ± 4	57 ± 5.6	30 ± 14	49 ± 20
Asian or Pacific Islander	51 ± 9	53 ± 9	48 ± 11	54 ± 7
Hispanic or Mexican American	48 ± 9‡	50 ± 10†	46 ± 11‡	53 ± 10‡
Smoking				
Current	48 ± 9	52 ± 8	46 ± 11	52 ± 10
Ex-Smoker and Never	49 ± 9	54 ± 8§	46 ± 10	55 ± 8*
Marital Status				
Married	49 ± 9	54 ± 7	47 ± 10	55 ± 7
Widowed	45 ± 11	54 ± 8	43 ± 11	55 ± 8
Divorced/Separated	49 ± 10	52 ± 9	46 ± 11	54 ± 9
Never Married	49 ± 8†	54 ± 9‡	46 ± 11†	53 ± 9‡
Education, years				
< 9	45 ± 10	53 ± 10	41 ± 11	55 ± 9
9-12	48 ± 9	54 ± 8	45 ± 11	55 ± 8
13-16	48 ± 10	54 ± 8	46 ± 11	55 ± 8
> 16	50 ± 8†	55 ± 7‡	49 ± 9†	55 ± 7
BMI				
< 30	50 ± 8	54 ± 7	48 ± 10	55 ± 8
≥ 30	46 ± 10*	54 ± 8	44 ± 11*	55 ± 8
Chronic Heart Disease				
Yes	44 ± 10	54 ± 8	41 ± 11	55 ± 8
No	50 ± 9*	54 ± 8	47 ± 10*	55 ± 8
Respiratory Disease				
Yes	44 ± 10	51 ± 10	41 ± 12	54 ± 9
No	49 ± 9*	54 ± 8*	47 ± 10*	55 ± 8§
Takes Sleeping Pills				
Yes	47 ± 10	52 ± 9	44 ± 11	53 ± 9
No	49 ± 9*	55 ± 7*	47 ± 10*	55 ± 7*
RDI				
< 5	49 ± 9	54 ± 8	48 ± 10	55 ± 7
5 - < 15	48 ± 9	54 ± 8	46 ± 10	55 ± 8
15 - < 30	47 ± 9	55 ± 8	45 ± 11	54 ± 8
≥ 30	45 ± 10†	55 ± 8	44 ± 11†	56 ± 7
DIMS				
Yes	46 ± 10	52 ± 9	44 ± 11	53 ± 9
No	50 ± 9*	55 ± 7*	48 ± 10*	55 ± 7*
ESS ≥ 11				
Yes	47 ± 10	53 ± 9	44 ± 11	54 ± 9
No	49 ± 9§	55 ± 7*	47 ± 10*	55 ± 7*

*P-values < 0.0001 for *t*-test for PCS and MCS by descriptive variables. §P-values < 0.05 for *t*-test for PCS and MCS by descriptive variables. †P-values < 0.0001 for one-way analysis of variance for PCS and MCS by descriptive variables. ‡P-values < 0.05 for one-way analysis of variance for PCS and MCS by descriptive variables.

Linear Regressions

Unadjusted linear regression models showed that a unit increase in the change in RDI was associated with an average decrease of 0.042 units in PCS (P = 0.02), but no association was seen with MCS (data not shown). A unit increase in DIMS was associated with an average decrease of 0.85 units in PCS (P = 0.05) and 0.76 units in MCS (P < 0.0001). However, a unit increase in change in ESS was associated with an average decrease of 1.61 units in PCS (P < 0.001) and 1.2 units in MCS (P = 0.007).

After adjusting for covariates, multiple linear regression models showed no significant association between change in RDI and changes in PCS or MCS (Table 3). Adjusted models continued to show significant associations between change in DIMS and change in MCS, but not between DIMS and the PCS (Table 4). A unit increase in the change in DIMS was associated with an average decrease in MCS of 1.03 units (P = 0.03). Likewise, as shown in Table 5, change in sleepiness status (ESS ≥ 11) was associated with change in the PCS (coefficient = -1.56, P = 0.002) and with change in MCS (coefficient = -1.54, P = 0.004). Increases in

Table 3—Multiple Linear Regression Models Predicting Change in PCS and MCS by Change in RDI Adjusted for Difference and Baseline Variables*

	Coefficient	P-value
PCS change		
Difference Variables		
RDI4%	-0.03	0.11
Age	-0.31	0.43
BMI	-0.17	0.03
Smoke	-0.32	0.77
Takes Sleeping Pills	-1.49	0.003
Baseline Variables		
RDI4%	0.008	0.68
Age	-0.06	< 0.001
BMI	-0.04	0.28
CHD	-0.21	0.70
Respiratory Disease	-0.18	0.78
Smoke	-0.18	0.81
Sex (Male)	0.45	0.23
Takes Sleeping Pills	-1.49	0.003
Constant	4.7	0.09
MCS change		
Difference Variables		
RDI4%	-0.02	0.31
Age	0.07	0.87
BMI	0.20	0.01
Smoke	-1.72	0.15
PSG Total Sleep Time	0.01	0.001
Baseline Variables		
RDI4%	-0.02	0.32
Age	0.03	0.19
BMI	0.03	0.51
CHD	0.28	0.63
Respiratory Disease	0.38	0.58
Smoke	-1.76	0.02
Sex (Male)	-0.35	0.40
PSG Total Sleep Time	0.006	0.11
Constant	-4.4	0.24

*RDI, Age, BMI, and PSG Total Sleep Time are continuous variables. CHD, Respiratory Disease, and Takes Sleeping Pills are Yes/No dichotomous variables, and No is the reference category. Smoke is categorized into Never vs Current and Ex-smokers and Never is the reference category. Female is the reference category for Sex. Change and difference variables were computed by subtracting follow-up values from baseline values.

Table 4—Multiple Linear Regression Models Predicting Change in PCS and MCS by Change in DIMS Adjusted for Difference and Baseline Variables*

	Coefficient	P-value
PCS change		
Difference Variables		
DIMS	-0.70	0.12
Age	-0.30	0.44
BMI	-0.17	0.02
Smoke	0.24	0.83
Takes Sleeping Pills	-1.36	0.009
Baseline Variables		
DIMS	-0.75	0.26
Age	-0.06	< 0.001
BMI	-0.04	0.33
CHD	-0.16	0.76
Respiratory Disease	0.03	0.96
Smoke	-0.19	0.80
Sex (Male)	0.44	0.24
Takes Sleeping Pills	-1.18	0.02
Constant	4.51	0.110
MCS change		
Difference Variables		
DIMS	-1.03	0.03
Age	0.09	0.83
BMI	0.19	0.02
Smoke	-1.89	0.12
PSG Total Sleep Time	0.01	0.001
Baseline Variables		
DIMS	0.17	0.73
Age	0.03	0.19
BMI	0.01	0.74
CHD	0.14	0.81
Respiratory Disease	0.37	0.60
Smoke	-1.81	0.02
Sex (Male)	-0.41	0.32
PSG Total Sleep Time	0.007	0.08
Constant	-4.4	0.23

*DIMS difference is a discrete -1, 0, 1 variable. Age, BMI, and PSG Total Sleep Time are continuous variables. DIMS, CHD, Respiratory Disease, and Takes Sleeping Pills are Yes/No dichotomous variables, and No is the reference category. Smoke is categorized into Never vs Current and Ex-smokers and Never is the reference category. Female is the reference category for Sex. Change and difference variables were computed by subtracting follow-up values from baseline values.

BMI and taking sleeping pills were significantly associated with increase in PCS, whereas increases in BMI and polysomnography total sleep time were associated with increase in MCS. These models show that changes in RDI were not associated with variations in PCS or MCS. However, changes in DIMS were associated with changes in MCS and changes in ESS were associated with changes in both, PCS and MCS. Therefore increases in DIMS and ESS score of 11 or greater were significantly associated with decreases in physical and mental components of quality of life.

DISCUSSION

The present longitudinal evaluation showed that, over the course of approximately 5 years, there was only a modest median increase in the severity of SDB, as assessed by polysomnography; this was not associated with worsening of either mental or physical quality of life. However, self-reported worsening in initiating and maintaining sleep was associated with poorer mental quality of life, and worsening of daytime sleepiness symptoms was associated with both poorer physical and mental quality of life.

In the present study, 38% of subjects with an RDI less than 5 during the baseline remained stable during the follow-up, and 14% of subjects with an RDI of 5 to less than 15 remained stable from baseline to follow-up. Marked increases in RDI from less than 5 at baseline to 30 or more at follow-up were uncommon, seen in less than 1% of the cohort. Marked decreases in RDI from 30 or higher at baseline to less than 5 or to 5 to less than

Table 5—Multiple Linear Regression Models Predicting Change in PCS and MCS by Change in ESS Adjusted for Difference and Baseline Variables*

	Coefficient	P-value
PCS change		
Difference Variables		
ESS	-1.56	0.002
Age	-0.15	0.70
BMI	-0.16	0.04
Smoke	0.16	0.88
Takes Sleeping Pills	-1.45	0.005
Baseline Variables		
ESS ≥ 11	-1.05	0.04
Age	-0.06	0.001
BMI	-0.03	0.35
CHD	-0.30	0.58
Respiratory Disease	0.16	0.80
Smoke	-0.41	0.58
Sex (Male)	0.48	0.20
Takes Sleeping Pills	-1.41	0.005
Constant	3.68	0.19
MCS change		
Difference Variables		
ESS	-1.54	0.004
Age	-0.05	0.91
BMI	0.20	0.01
Smoke	-2.21	0.07
PSG Total Sleep Time	0.01	0.01
Baseline Variables		
ESS ≥ 11	0.24	0.66
Age	0.02	0.24
BMI	0.02	0.66
CHD	0.44	0.47
Respiratory Disease	0.75	0.28
Smoke	-1.91	0.01
Sex (Male)	-0.41	0.32
PSG Total Sleep Time	0.008	0.05
Constant	-4.15	0.27

*ESS difference is a discrete -1, 0, 1 variable. Age, BMI, and PSG Total Sleep Time are continuous variables. ESS ≥ 11, CHD, Respiratory Disease, and Takes Sleeping Pills are Yes/No dichotomous variables, and No is the reference category. Smoke is categorized into Never vs Current and Ex-smokers and Never is the reference category. Female is the reference category for Sex. Change and difference variables were computed by subtracting follow-up values from baseline values.

15 at follow-up were infrequent as well. Despite differences used in measuring SDB severity and in event definition, our findings are remarkably similar to data reported from the Cleveland Family Study in which the mean RDI increased from 6.0 per hour to 8.6 per hour over approximately 5 years, as well as those from the Wisconsin Sleep Cohort, which noted that RDI increased from 4.1 per hour to 5.5 per hour over approximately 4 years.[29,30] Taken together, our data and those of others indicate that SDB is slowly progressive over time, although there are some instances in which accelerated progression or rapid improvement occurs.

In this study, we did not find that alterations in quality of life were independently related to change in severity of SDB, as assessed by polysomnography, or that there was an association between DIMS and physical quality of life. In contrast, cross-sectional analyses from the first examination in SHHS demonstrated that severe SDB was associated with a reduction in vitality but not with any of the other SF-36 subscales.[9] However, in the present study, DIMS was strongly associated with lower mental quality of life, and sleepiness was strongly related to lower physical and mental quality of life. Although microarousals are frequently observed on polysomnography following apneas and hypopneas, the correlation between symptoms of disturbed sleep and severity of SDB on polysomnography is modest at best. For example, in the SHHS, the prevalence of sleepiness as defined by an ESS score greater than 10 is 46% for those subjects with an apnea-hypopnea index of 30 or greater.[31] Thus, it is not surprising that we found little independent contribution of the RDI to changes in quality of life. In this study, subjects with an ESS score of 11 or greater had higher mean RDI associated with a 4% or greater desaturation (10.2) than did those subjects with lower ESS values (7.2, $P < 0.001$) at baseline and, similarly, at follow-up (13.2 and 10.2, $P < 0.001$). However, mean differences in RDI associated with a 4% or greater desaturation for DIMS were not significant.

In contrast with the absence of an independent effect of RDI, we found that a longitudinal increase in the DIMS was associated with a decline in mental components of quality of life. As noted previously, this observation is consistent with cross-sectional analyses from the first examination cycle of the SHHS.[9] The point prevalence of insomnia is estimated to be approximately 30%, with chronic insomnia occurring in 10% of the general population. Several epidemiologic studies have determined that the prevalence of DIMS is approximately 30%, with reports approaching 50% in the elderly.[32,33] Population studies have found higher odds for insomnia in women than in men (odds ratio 1.5).[34]

Although we found lower scores for the physical and mental component scales for women, compared with men, at baseline and follow-up, sex was not a significant predictor for declining quality of life once our models were adjusted for other covariates. Except at baseline for PCS, age also was not a factor associated with changes in quality of life. Furthermore, insomnia has been shown to be predictive of subsequent depression, and, in a number of studies, insomnia was associated with physical comorbidities such as CHD.[35,36] These results extend previous reports by demonstrating that changes in DIMS are associated with corresponding changes in mental quality of life. These findings reinforce the concept that subjective sleep quality is an important determinant of health-related quality of life.

Our study found significant associations with longitudinal increases in EDS and worsening of physical and mental scales of quality of life. EDS has been correlated with insomnia, depression, daytime alertness, cognitive performance, and quality of life.[6,37,38] Sleepy persons are reportedly more sedentary and are less motivated to engage in social activities.[39] In addition, quality of life has been reported to be significantly impaired in subjects with SDB, and 1 or more SF-36 quality-of-life subscales have been found to be affected in both clinical and community-derived populations.[9,40] Inasmuch as changes in RDI were not found to be independently associated with quality of life, our data indicate that, in those subjects with SDB, it is the

presence of EDS that determines whether there will be an impact on quality of life.

The prevalence of CHD is reported to be 4.0% in the United States.[41] Women have lower rates of heart disease than do men[42]; however, women are more likely to die from myocardial infarctions than are men.[43] Studies have demonstrated that subjects who have myocardial infarctions have lower overall health-related quality of life.[43] Compared with normative data, Brink et al.[44] reported lower physical and mental health-related quality of life in a group of 114 subjects 5 months after they experienced an acute myocardial infarction. Our study evaluated a combination of several heart-related conditions and found significant associations with physical, but not mental, health-related quality of life at baseline and follow-up. Thus, our data would suggest that physical limitations imposed by the presence of heart disease adversely impact physical components of quality of life. However, despite evidence in clinical population studies that heart disease[45] is associated with depression, in this community population, we did not find an association between CHD and higher MCS.

Chronic bronchitis and chronic obstructive pulmonary disease have also been associated with decreased health-related quality of life.[46] Some studies have found that quality of life may be associated with increased mortality and exacerbation of COPD.[47,48] In the present study, physical and mental health components were lower for subjects with than for those without respiratory diseases at baseline and follow-up. However, neither CHD nor respiratory diseases were associated with decrease in either physical or mental health-related quality of life in adjusted regression models.

Obesity is a significant public health concern in Western countries.[49,50] Higher levels of BMI have been associated with increased morbidity and mortality in chronic diseases such as diabetes, heart disease, SDB, and others.[51] Similarly, the association between BMI and quality of life has been investigated in different populations. Studies have found excess body weight to be primarily associated with physical rather than than mental health-related quality of life.[52] Consistent with previous studies, we found that obese subjects had a lower PCS scores, as compared with nonobese subjects, at baseline and follow-up surveys, whereas no difference in scores on the MCS for obese subjects was seen at baseline or follow-up. Longitudinal evaluation, however, showed that an increase in BMI was associated with lower PCS but higher MCS scores of quality of life. Thus, our findings are consistent with findings from other studies with respect to physical components but not mental components of quality of life.

In conclusion, results from this study show that longitudinal worsening of quality of life is associated with subjective symptoms of sleep disturbances but not polysomnography-derived severity of SDB. These data promote the concept that perception of sleep quality and not standard objective measurements of sleep quality have the most sleep-related impact on quality of life.

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