Sleep and Reported Daytime Sleepiness in Normal Subjects: the Sleep Heart Health Study

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Study Objectives: To describe the distribution of nocturnal sleep characteristics and reports of daytime sleepiness in a large well-defined group of healthy adults.

Design: The Sleep Heart Health Study is a multicenter study examining sleep and cardiopulmonary parameters through nocturnal polysomnography in adults enrolled in geographically distinct cardiovascular cohorts.

Setting: Community setting.

Participants: 470 subjects enrolled in the Sleep Heart Health Study (n = 6440) were selected as a 'normative' group based on screening of health conditions and daily habits that could interfere with sleep.

Measurements and Results: Home-based nocturnal polysomnography was obtained on all participants and centrally scored for sleep and respiratory parameters. Demographic and health-related data were obtained and updated at the time of the home visit. Sleep efficiency decreased by 1.6% for each 10 years of increased age. Sleep time decreased by 0.1 hours (6.0 minutes) for each 10-year age increase and was longer in women. The arousal index increased by 0.8 for each 10-year increase in age and was lower by 1.4 in women. Women had a lower mean percentage of stage 1 and stage 2 sleep. Mean percentage of slow-wave sleep was higher in women (by 6.7%). Percentage of slow-wave sleep decreased with increased age for men only (by 1.9% for each 10-year age change).

Conclusions: Data suggest a clear lessening in the quantity and quality of sleep with age that appears to be more rapid in males compared to females.

Key Words: Sleep Heart Health Study, home-based polysomnography, normal subjects, gender, sleep

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INTRODUCTION

NORMATIVE DATA ARE ESSENTIAL FOR UNDERSTANDING SLEEP PHYSIOLOGY AND FOR ASSESSING PATIENTS IN CLINICAL PRACTICE. Yet there has been little documentation of normative values for sleep stages in large well-defined populations, either in laboratory settings or at home. The most-cited study is that of Williams and Karacan,[1] who studied sleep stages in healthy persons in a laboratory setting. These data are limited by the small sample size. Stratified by sex and decade of age, each stratum was represented by only 10 to 12 subjects. Additionally, it is unclear whether subjects in this study were free of characteristics that may be associated with disrupted sleep. Furthermore, although well controlled for laboratory variability and scorer reliability, the laboratory setting could have affected the sleep parameters. A more recent study of sleep in healthy persons established norms for the Maintenance of Wakefulness Test and provided additional normative values for laboratory-based nocturnal polysomnography in a similar-sized sample.[2] Other smaller laboratory-based studies may have had limited power to detect differences between sexes or had poorly specified determination of 'healthy' or 'normal' subjects.[3-5] Most studies look at young adults. However, Hoch et al[6] did examine the sleep of 50 'young old' (aged 60-74 years) and 50 'old old' (ages > 75 years) healthy subjects longitudinally over 2 years, providing additional information on the effect of aging on sleep parameters. One study that did attempt to monitor sleep in the home environment utilized actigraphy (a surrogate method of scoring sleep versus wake using body movements) and studied a larger group of subjects.[7] This study provided some general knowledge of sleep and rest activity across ages. Still others have studied daytime symptoms using subjective scales of sleepiness[8-10] to provide insight into the impact of sleep and sleep loss.

The Sleep Heart Health Study (SHHS), a large multicenter study designed to examine the relationship between sleep-disordered breathing and cardiovascular disease in more than 6000 subjects, provides a unique opportunity to examine data from home-based polysomnography in subjects who have been well characterized for conditions that might disrupt sleep. Of this group, 470 subjects were selected to form a well-characterized adult group (not necessarily representative of the SHHS cohort) but, instead, those who are free of health conditions and daily habits that could interfere with sleep. We describe nocturnal sleep and daytime sleepiness of this relatively healthy community-based adult sample that is free of known sleep-disrupting factors.

METHODS

The design of the SHHS has been described elsewhere.[11] Briefly, the study enrolled 6440 subjects, over 40 years of age, from existing geographically distinct cohorts that were initially assembled between 1976 and 1995. These include the Offspring Cohort and the Omni Cohort of the Framingham Heart Study in Massachusetts; the Cardiovascular Health study in Allegheny

County, Pa, Sacramento County, Calif, and Washington County, Md; the Atherosclerosis Risk in Communities Study of Minneapolis, Minn, and Washington County, Md; the Hypertension Cohorts (Clinic,

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Worksite and Menopause) at Cornell Hypertensive Center in New York City; the Tucson Epidemiologic Study of Airway Obstructive Diseases and the Health and Environment Study; and the Strong Heart Study of American Indians in Oklahoma, Arizona, North Dakota, and South Dakota. Consents were obtained in accordance with individual institutional review boards.

Demographic and health-related data were available for each subject. These were updated during the most recent parent cohort exam, as well as during the home polysomnography visit. In addition, SHHS administered a Sleep Habits Questionnaire to assess the presence of sleep disorders, abnormal sleep habits, and social habits such as smoking and alcohol use that are known to interfere with sleep. The Epworth Sleepiness Scale (ESS),[12] a subjective scale of one's propensity to fall asleep in sedentary situations, was included as part of the Sleep Habits Questionnaire. The prevalence of chronic illnesses such as angina, diabetes, hypertension, and myocardial infarction in this population was obtained from the self-report information of the parent cohorts. Prevalence was defined as the percentage of *yes* responses out of the total of *yes* and *no* responses for that illness. Absence of chronic disease was defined as a *no* or *unsure* response for that data item.

Full polysomnography was carried out in the home using the Compumedics P Series System (Abbotsford, Victoria, Australia) administered by trained technicians. The montage for sleep staging included electroencephalogram (C3/A2, C4/A1), submental electromyogram, and electrooculogram. Sleep and arousals were scored according to Rechtschaffen and Kales criteria.[13,14] Leg movements were not monitored due to safety considerations. We were concerned that, in this older cohort, the sensors necessary to record leg movements may trip subjects as they rose from bed. Stringent protocols for comparability between centers and technicians were maintained. Technician reliability was high.[15] For purposes of SHHS, the respiratory disturbance index (RDI) was scored with 5 different oxygen desaturation criteria: number of apneas (< 25% of baseline airflow) and hypopneas (< 70% of baseline airflow) per hour of sleep without regard to any oxygen desaturation, and using a 2%, 3%, 4%, or 5% oxygen desaturation criteria to define the respiratory event.

Subjects for this analysis were chosen from the lower half of the distribution (below the median) of 2 measurements: RDI without regard to oxygen desaturation (median RDI, 29), and RDI based on 4% oxygen desaturation ([RDI 4%] median RDI, 4.37). These 2 criteria define somewhat different groups because 23.2% of subjects who had an RDI based on 4% desaturation values below the median still had RDI values above the median when oxygen desaturation was disregarded. Excluding subjects with values above the median for either category eliminated individuals with an increased number of subtle respiratory events as well as those with more severe events.

As noted in Table 1, subjects were excluded if they had a body mass index (BMI, kg/m^2) < 16 or > 30; history of stroke, heart failure, chronic obstructive pulmonary disease, emphysema, asthma attack in the last 12 months or self-reported apnea; reports of frequent sleep disturbance due to *often* or *always* experiencing nocturnal leg cramps, heartburn, joint pain, dyspnea, chest pain; mood disturbance such as *often* or *always* feeling blue or down; symptoms of insomnia, such as having trouble falling asleep, awakening during the night, or early morning awakenings; use of any of the following substances within 4 hours of the sleep period: cigarettes, caffeine, or alcohol, including wine and beer; > 10 caffeinated beverages per day, > 14 servings of alcohol per week, or both; use of medications that interfere with sleep, including sleeping pills *often* or *always* and any psychotropic drugs such as benzodiazepines, tricyclic antidepressants, or antipsychotic combinations, monoamine oxidase inhibitors, or serotonin reuptake inhibitors. Seventy-five habitual snorers (reporting snoring frequently or almost always 3 or more nights per week) met the criteria for the normative population. There were no significant differences in mean arousal index or sleep stages when compared to nonsnorers, but snorers had less total sleep time (5.9 hours versus 6.3 hours) and higher RDI 4% (1.6 versus 1.2). They also had higher ESS scores (9.1 versus 6.5). Since they did not vary significantly on sleep quality based on staging and arousals, they were included.

A total of 470 subjects had polysomnograms that were of sufficient quality to reliably determine sleep stages and arousals and were included in our final sample (Caucasian, n = 372; African American, n = 40; Hispanic, n = 33; Asian, n = 17; and American Indian, n = 8). Sleep variables available in all our subjects included rapid-eye-movement (REM) latency from sleep onset, percentage of sleep time in specific stages, arousal index (number of arousals meeting American Academy of Sleep Medicine criteria per hour of sleep), awakening index (number of transitions from sleep to an epoch of wake per hour of time in bed), and total sleep time. Sleep latency (time from lights out to onset of sleep) was available in a subset of subjects in whom the time of lights out could be determined reliably and the recording period did not begin in a sleep state (n = 276). Sleep efficiency (percentage of sleep time out of total dark time) was available in a subset of subjects in whom the time of lights out could be determined reliably and the recording period did not begin or end in a sleep state (n = 199). The REM latency from sleep onset was available in the subset in whom the recording period did not begin in a sleep stage (n = 441). Studies excluded from analysis of sleep latency, sleep efficiency, and REM latency were not excluded from analyses of other sleep parameters after confirming that the results of those analyses were not significantly changed by their inclusion. All subjects were usual nocturnal sleepers.

Data Analysis

Continuous variables were compared for different age and sex groups using either the Kruskal-Wallis or Mann-Whitney test. Binary variables were compared between different groups using the χ^2 test. All analyses were performed using SPSS data analysis software (SPSS for Windows: base system user's guide, release 6.0, SPSS, Inc., Chicago, Ill 1993). A P value ≤ .05 was used as the cut-off for statistical significance.

Multiple linear regression was performed with individual sleep variables or the ESS score as the dependent variable to assess the influence of age and sex on specific parameters and whether an age or sex interaction was present. The BMI was included as a covariate. Continuous variables (age and BMI) were centered by subtracting their mean values. In addition, multivariate analysis was performed with the previously mentioned dependent variables to assess whether differences were pre-

Table 1—Exclusion criteria for 6440 subjects from Sleep Heart Health Study cohort to obtain subset used in analysis*

Criteria	Total, no.	% of Total
RDI 4% > 50th percentile	3220	50.0
RDI > 50th percentile	3220	50.0
BMI < 16 or BMI > 30	2081	32.3
Self-reported chronic illness*	750	11.6
Complaint of frequent awakenings†	1759	27.3
Report of current depressed mood‡	116	1.8
Complaint of frequent insomnia§	1943	30.2
Tobacco or caffeine use < 4 hours before study	2189	34.0
Excessive alcohol (> 14/week) or caffeine use (> 10/day)	311	4.8
Often use sleeping pills	483	7.5
Medication use¦	691	10.7
Inadequate study quality	1649	25.6

*Self-report of stroke, heart failure, chronic obstructive pulmonary disease, emphysema, sleep apnea, or asthma attack within 12 months.
†Often or almost always awaken with leg cramps or leg jerks; heartburn or indigestion; pain in joint, muscles or back; shortness of breath; or chest pain or tightness.
‡Most or all of the time down hearted and blue or down in the dumps.
§Often or almost always have trouble falling asleep, wake up during night, or wake up too early.
¦Use benzodiazepines, tricyclic antidepressant, nontricyclic antidepressant, or antipsychotic medication.
RDI 4% refers to respiratory disturbance index associated with a 4% decrease in oxygen saturation; BMI, body mass index.
Note: Numbers excluded for each reason do not add up to total number excluded because each subject may meet more than 1 exclusion criteria.

sent between racial or ethnic groups after adjustment for age, sex, age and sex interaction (if significant), BMI, education (as a measure for socioeconomic status), and marital status.

Subjects with ESS scores in the top quintile (≥ 10) were compared with those in the lower quintiles using the χ^2 test for binary variables or the Mann-Whitney test for continuous variables.

RESULTS

Descriptive statistics are shown in Table 2a and 2b. The majority of subjects were women (65.1%). Mean self-reported sleep duration was 7.3 hours on weekdays and 7.8 hours on weekends for the women and 7.1 hours on weekdays and 7.6 hours on weekends for the men. A small percentage of subjects complained of frequently feeling sleepy (5.2%) or unrested (6.7%). The prevalence of self-reported sleepiness and feeling unrested was highest in the 40- to 54-year-old age group. Sleep duration on weekends decreased significantly with increasing age. Sleep duration on weekdays increased slightly within older age groups, though the difference between age groups was not statistically significant. Mean prevalence of self-reported alcohol and caffeine consumption was considered moderate. The prevalence of certain chronic illnesses increased with age. Self-reported hypertension was quite prevalent (29.8%).

Tables 3a to 3c show mean, median, 10th, and 90th percentile values for sleep parameters for the entire group and specific age and sex categories. Mean values are in bold when the specific parameters were approximately normally distributed (percentage stages 2, 3, and 4 [slow-wave sleep, SWS] and REM sleep). For parameters with skewed distributions, median values are highlighted. Table 3a shows sleep parameters stratified by sex, as well as values for the combined sample. Women had significantly longer REM latencies and sleep times, lower arousal and awakening indexes, lower percentages of stages 1 and 2 sleep, and higher percentages of SWS (stages 3 and 4) than men. Table 3b shows that age categories differed significantly with respect to sleep latency, sleep efficiency, sleep time, percentage of stage 2 sleep, and percentage of SWS. Sleep latency was longer, while sleep efficiency was lower and sleep time was shorter in the older age groups. The percentage of stage 2 sleep was lowest in the 55- to 69-year-old age group and highest in the 70- to 91-year-old age group. The percentage of SWS was highest in the 55- to 69-year-old age group and lowest in the 70- to 91-year-old age group. Table 3c shows the sleep parameters stratified by age and sex. Compared to men, women had more SWS in each age category and a longer REM latency in the middle- and older-aged groups. Compared to women, men had higher arousal and awakening indexes in each of the age categories.

Table 4 gives the results of multivariate regression analysis of sleep parameters that include age, sex, BMI, and the age-sex interaction term (if significant) as independent variables. The following is a summary of statistically significant findings. The mean REM latency was 10.2 minutes longer in women than in men. Sleep efficiency decreased by 1.6% for each 10-year age increase. Sleep time decreased by 0.1 hours (6.0 minutes) for each 10-year age increase and was longer in women by 0.3 hours (18 minutes). The arousal index was lower by 1.4 arousals per hour in women. Mean awakening index was 0.6 awakenings per hour lower in women. Women had a lower mean percentage of stage 1 sleep (by 1.1%) and mean percentage of stage 2 sleep (by 6.0%). The mean percentage of SWS was higher in women (by 6.7%). The change in percentage of SWS with change in age was different between men and women. The percentage of SWS was 1.9% lower for each 10-year age increase for men but was 0.5% higher for the same age increase in women.

Sleep parameters for African American, Hispanic, Asian, and American Indian subjects were compared to Caucasians. After adjusting for age, sex, BMI, education, and marital status, the following comprised the statistically significant findings. African Americans had a higher percentage of stage 2 sleep (by 9.0%, $P < .001$), a lower percentage of SWS (by 5.1%, $P < .03$), a lower percentage of REM sleep (by 2.7%, $P < .03$), and a shorter sleep time (by 0.5 hours, $P < .03$) than Caucasians. American Indians had a lower percentage of SWS than Caucasians (by 8.2%, $P < .05$).

Table 2a—Characteristics of 164 Men

	All N = 164	Age group, y 40-54 n = 53	55-69 n = 65	70-91 n = 46
Age*, y				
Mean (SD)	60.8 (11.8)	47.6 (4.5)	61.0 (4.2)	75.7 (4.8)
Median	59.0	48.0	60.0	75.0
BMI, kg/m^2				
Mean (SD)	25.6 (2.5)	25.1 (2.4)	25.9 (2.5)	25.7 (2.8)
Median	25.8	25.3	25.8	25.9
Education*, y				
Mean (SD)	15.4 (3.3)	16.1 (2.7)	15.6 (3.6)	14.3 (3.2)
Median	16.0	16.0	16.0	15.0
Habitual snorers, %	25.6	20.8	35.4	17.4
Weekday sleep, h				
Mean (SD)	7.1 (1.1)	6.9 (1.0)	7.2 (1.1)	7.1 (1.1)
Median	7.0	7.0	7.0	7.0
Weekend sleep, h				
Mean (SD)	7.6 (1.1)	7.6 (0.9)	7.8 (1.1)	7.4 (1.1)
Median	8.0	8.0	8.0	7.0
Alcohol, servings/wk				
Mean (SD)	2.5 (3.6)	2.1 (3.0)	2.9 (3.8)	2.5 (3.9)
Median	1.0	0.8	2.0	0.0
Caffeine, servings/d				
Mean (SD)	2.6 (2.1)	2.8 (2.4)	2.9 (2.0)	2.0 (1.8)
Median	2.0	2.0	3.0	2.0
Current smokers, %	1.8	1.9	3.1	0.0
Angina, %	6.2	2.0	9.4	6.5
Diabetes, %†	8.2	0.0	14.8	8.7
Hypertension, %†	35.2	15.1	40.6	51.1
Myocardial infarction, %†	7.5	2.0	7.8	13.0
Frequently sleepy, %	2.5	3.8	3.2	0.0
Frequently unrested, %†	6.2	15.4	1.6	2.2

*P value ≤ .05 comparing age categories using Kruskal-Wallis test.
†P value ≤ .05 comparing age categories using χ^2 test.
BMI refers to body mass index.

Table 2b—Characteristics of 306 Women

	All N = 306	Age group, y 40-54 n = 104	55-69 n = 132	70-91 n = 70
Age, y*				
Mean (SD)	59.6 (11.2)	47.7 (4.7)	60.6 (4.3)	75.2 (4.5)
Median	58.0	48.0	59.0	74.0
BMI, kg/m^2				
Mean (SD)	24.6 (2.9)	24.4 (2.9)	24.7 (2.8)	24.9 (3.0)
Median	24.8	24.5	25.0	25.1
Education, y*				
Mean (SD)	14.6 (3.4)	15.7 (2.5)	14.8 (3.6)	12.9 (3.4)
Median	14.0	16.0	14.0	12.0
Habitual snorers, %	10.8	5.8	15.2	10.0
Weekday sleep, h				
Mean (SD)	7.3 (1.0)	7.3 (0.8)	7.3 (1.0)	7.4 (1.2)
Median	7.0	7.0	7.0	8.0
Weekend sleep, h				
Mean (SD)	7.8 (1.1)	8.1 (1.0)	7.7 (1.0)	7.5 (1.3)
Median	8.0	8.0	8.0	8.0
Alcohol, servings/wk				
Mean (SD)	1.2 (2.3)	1.0 (1.8)	1.4 (2.4)	1.2 (2.8)
Median	0.0	0.0	0.0	0.0
Caffeine, servings/d				
Mean (SD)	1.8 (1.8)	1.9 (1.8)	1.8 (1.8)	1.5 (1.9)
Median	1.0	2.0	1.0	1.0
Current smokers, %	1.6	1.0	2.3	1.4
Angina, %	3.3	1.9	3.1	5.8
Diabetes, %†	1.7	1.0	1.5	2.9
Hypertension, %†	26.2	15.5	24.2	45.7
Myocardial infarction, %†	1.7	1.0	0.8	4.3
Frequently sleepy, %	6.6	8.7	3.1	10.0
Frequently unrested, %†	7.0	10.8	5.4	4.3

*P value ≤ .05 comparing age categories using Kruskal-Wallis test.
†P value ≤ .05 comparing age categories using χ^2 test.
BMI refers to body mass index.

Mean and median ESS scores were 6.9 and 6.0 respectively. Multivariate regression analysis did not reveal any significant relation of the ESS score to age, sex, or BMI. Almost a quarter (23.9%) of our subjects had an ESS score of 10 or greater. Men and women with an ESS score 10 or greater were compared to those with scores less than 10 (Table 5a and Table 5b). Subjects with high ESS scores were more likely to be habitual snorers (21.5% of women; 34.9% of men). They also complained more frequently of often not getting enough sleep (16.7% men; 16.9% women) and reported shorter weekday and weekend sleep duration. For women, a shorter REM latency in subjects with an ESS score > 10 was the only significant difference in objective sleep-stage parameters. For men, these measures were not significantly different for subjects with an ESS > 10, though they were shorter.

CONCLUSION

This analysis describes the distribution of sleep stages in a large well-defined group of healthy subjects over 40 years of age studied with polysomnography in their home environment. Our population was developed by excluding those individuals with symptoms that could interfere with sleep, rather than just by disease state. This ensured that subjects whose diseases were in good control and not interfering with sleep could be included. Therefore, this sample showed expected increases in prevalence of certain chronic conditions with age. The study sample included a few subjects who smoked and drank caffeinated and alcoholic beverages in moderation.

This sample of adults reported sleeping a mean of 7.2 hours during the week and 7.7 hours on weekends. These figures changed with age such that reported weekday sleep increased while weekend sleep decreased. Our findings compare well to another survey of American adults. The average hours slept reported by commuters (N = 4714) on the Long Island Rail Road showed a similar pattern (6.9 hours during the week and 8.2 on the weekend).[9] Therefore, the sleep times of our participants may reflect scheduling needs more than ability to sleep. Individuals of a typical working age may tend to shorten sleep during the week and attempt to make it up on weekends, while this scheduling may become unnecessary when one reaches retirement age. Our subjects' self-reported sleep times were somewhat higher than their objectively measured nocturnal sleep times. This may indicate that there was overestimation of sleep time by our participants or that they altered their normal sleep duration on the night of the study. In the normative study of the Maintenance of Wakefulness Test, nocturnal sleep times showed that even when available sleep time was held constant to 8 hours, average laboratory nocturnal sleep time of a wide age range of adults was 6.8 hours.[2]

Overall our data suggest that, in general, women had better and longer sleep than did men across all ages. They had longer sleep times, lower arousal index, lower mean awakening index, more SWS, and less stage 1 and stage 2 sleep compared to men. The SWS decreased in men across this age group but not in women. This is consistent with data reported by Williams.[1] Our subjects had about the same amount of REM sleep and stage 2 sleep but less stage 1 sleep than reported by Williams. Both men and women in our sample had more SWS than noted by Williams and by Hoch et al.[6] In the study by Hoch, SWS in those aged 60 to 75 years was 5.4% (6.8) and decreased slightly over the 2-year follow up. However, in this study, the authors also noted the increase of 'mild' apnea and periodic leg movements over time. Our findings may reflect our rigorous selection criteria of healthy subjects or, again, a difference in study environment, ie, home versus laboratory. Other studies have reported significant levels of SWS in older subjects. Campbell and Murphy[16] studied middle-aged (40-60 years) and older (> 65 years) nondisturbed sleepers in a laboratory setting and noted the percentage of SWS to average 14.72 minutes and 11.52 minutes, respectively, with a SD of 8.52 and 8.17 minutes. The levels of SWS reported in our sample are in keeping with those of the entire SHHS cohort (as reported by Redline et al).[17] The findings of significant levels of SWS in these studies may argue for continued research to better understand and quantify the effect of aging or illness on SWS.

Table 3a—Sleep Parameters Presented by Sex

Sex	Sleep Latency, min	REM Latency*, min	Sleep Efficiency, %	Sleep Time*, h	Arousal Index*	Awake Index*	Stage 1*, %	Stage 2*, %	Stage 3/4*, %	Stage REM*, %
Men										
Mean	18.9	73.3	85.2	6.0	15.2	3.7	5.1	**58.3**	15.8	**20.8**
10th	6.5	28.0	74.0	4.8	7.4	2.0	1.7	44.5	1.8	13.6
50th	**15.5**	**64.3**	**85.7**	**6.1**	**14.3**	**3.5**	**4.2**	57.8	**14.8**	20.5
90th	32.0	121.5	93.4	7.2	23.8	5.8	9.5	70.5	30.1	29.2
n	91	152	60	164	164	164	164	164	164	164
Women										
Mean	19.1	84.7	85.9	6.3	13.8	3.1	4.0	**52.2**	22.8	**21.0**
10th	4.5	48.0	76.4	5.0	7.1	1.7	1.3	37.8	8.5	14.2
50th	**14.0**	**71.0**	**88.0**	**6.5**	**12.2**	**3.0**	**3.5**	52.0	**22.0**	21.2
90th	43.2	137.5	94.7	7.5	23.1	4.6	6.8	66.6	37.5	28.7
n	185	289	139	306	306	306	306	306	306	306
Both										
Mean	19.0	80.8	85.7	6.2	14.3	3.3	4.4	**54.3**	20.4	**20.9**
10th	5.0	43.1	74.9	4.9	7.2	1.8	1.4	39.6	5.4	14.1
50th	**14.5**	**68.5**	**87.6**	**6.4**	**13.1**	**3.1**	**3.7**	54.8	**20.0**	21.0
90th	39.5	135.4	94.4	7.4	23.4	5.1	7.7	68.3	34.9	28.9
n	276	441	199	470	470	470	470	470	470	470

*P value ≤ .05 comparing age categories using Kruskal-Wallis Test.
REM refers to rapid eye movement sleep; Arousal Index, number of arousals per hour of sleep; Awake Index, number of awakenings per hour of sleep.

Table 3b—Sleep Parameters for Specific Age Groups

Age group, y	Sleep Latency, min	REM Latency*, min	Sleep Efficiency, %	Sleep Time*, h	Arousal Index*	Awake Index*	Stage 1*, %	Stage 2*, %	Stage 3/4*, %	Stage REM*, %
40-54										
Mean	17.5	83.4	87.3	6.4	13.5	3.3	4.1	**55.1**	19.4	**21.4**
10th	3.4	46.0	77.5	5.1	7.0	1.9	1.5	43.5	6.8	14.8
50th	**13.3**	**74.5**	**89.3**	**6.5**	**12.6**	**3.1**	**3.6**	56.0	**19.0**	21.3
90th	40.9	124.0	94.4	7.4	21.3	5.1	6.9	66.9	30.5	28.9
N	106	151	79	157	157	157	157	157	157	157
55-69										
Mean	19.4	81.3	86.4	6.2	14.3	3.4	4.3	**52.4**	22.5	**20.8**
10th	5.5	43.2	77.3	5.1	7.5	1.8	1.3	36.2	6.8	14.1
50th	**14.5**	**67.0**	**88.3**	**6.3**	**13.0**	**3.2**	**3.5**	52.8	**22.0**	21.0
90th	37.6	140.0	95.1	7.5	23.3	5.1	7.9	67.3	39.4	27.7
N	105	183	75	197	197	197	197	197	197	197
70-91										
Mean	21.0	76.2	81.8	6.0	15.3	3.4	4.8	**56.6**	18.0	**20.7**
10th	7.0	38.2	70.0	4.6	6.9	1.7	1.3	42.1	2.9	12.6
50th	**18.5**	**66.0**	**83.3**	**6.1**	**13.7**	**3.2**	**4.0**	56.7	**17.1**	20.4
90th	34.0	135.3	93.6	7.3	27.2	5.2	9.5	71.7	33.8	30.0
N	65	107	45	116	116	116	116	116	116	116

*P value ≤ .05 comparing age categories using Kruskal-Wallis Test.
REM refers to rapid eye movement sleep; Arousal Index, number of arousals per hour of sleep; Awake Index, number of awakenings per hour of sleep.

Women also slept better than did men in the home-monitored actigraphy study by Reyner and Horne.[7] In contrast to the objective findings in our study, the older women in their study reported more awakenings and poorer sleep quality than did men. Similar findings are reported in a recent study of the effects of sleep-disordered breathing on sleep architecture, taken from a large portion of the SHHS study subjects. The finding of 'better' sleep in women compared to men held even when compared to those who were excluded for medication use or the presence of symptoms of disease.[17]

Our study showed a mean arousal index of 14.3, which increased with age and was higher in men than in women. This is lower than that observed by Mathur and Douglas,[4] who reported an average of 21 arousals per hour in their subjects and an increase in arousals with age, as well as that reported by Boselli et al[5] in laboratory studies. We are reassured by these data that we have not missed significant numbers of arousals caused by undetected periodic leg movements. The similarity to arousal indexes from laboratory-based studies that monitored leg movements suggests that this is not the case. We were unable to monitor other possible external interference in the home environment such as telephones, street noise, or that coming from children or pets. However, we note the decreased number of arousals in our data and feel that they may reflect the difference of in-laboratory versus in-home sleep, where the laboratory may be more disruptive. Regardless of that, frequent brief arousals do occur across sleep and, as Mather and Douglas note, may be an important aspect of normal sleep and should be considered as such in clinical studies.

Our data may also suggest that sleep differs between races. African Americans demonstrated shorter sleep time, higher amounts of stage 2 sleep, and lower amounts of SWS and REM sleep compared to Caucasians. The physiologic significance of this remains unclear. While the differences noted may be related to genetic differences, other sleep disorders that we did not measure may have played a role, as could cultural and environmental differences. We also recognize that our sample size of non-Caucasians is small and that we may have not adjusted for all relevant confounding factors. Further research should address this area.

Importantly, although the mean hours of self-reported sleep were at least 7.2 hours, almost a quarter of our subjects scored in a sleepy range (≥ 10) on the ESS. This is similar to findings from a 1997 Gallup Poll sponsored by the National Sleep Foundation, which examined sleepiness in America.[10] This poll reported that 32% of those contacted reported an ESS score of ≥ 10, and 6% reported a score of ≥ 15, clearly in the pathologic range. Whitney et al examined ESS data in more than 4000 elderly subjects from the Cardiovascular Health Study and noted similar sleepiness.[8] However, in their study, subjects complained about awakenings related to sleep complaints our cohort did not have, such as pain and leg cramps, which awakened them *often* across the night. In our study of well-screened adults, sleep deprivation and snoring appeared to strongly influence the subject's level of daytime sleepiness as measured by the ESS. This is consistent with findings reported by Gottlieb et al,[16] which showed that snoring was related to sleepiness after accounting for RDI.

Table 3c—Sleep Parameters for Specific Age/Sex Categories

Sex, Age group, y	Sleep Latency, min	REM Latency*, min	Sleep Efficiency, %	Sleep Time*, h	Arousal Index*	Awake Index*	Stage 1*, %	Stage 2*, %	Stage 3/4*, %	Stage REM*, %
Men, 1										
Mean	16.6	82.6	85.8	6.0	15.1	3.6	4.8	**56.5**	18.1	**20.7**
10th	3.5	43.0	73.2	4.2	7.4	2.4	1.8	41.0	5.6	14.6
50th	**13.8**	**76.5**	**87.5**	**6.1**	**15.5**	**3.5**	**4.0**	56.8	**15.8**	20.5
90th	36.0	121.5	93.3	7.1	22.1	5.6	7.5	68.9	32.2	28.4
N	34	51	21	53	53	53	53	53	53	53
Men, 2										
Mean	20.0	69.2	86.6	6.1	15.0	3.7	5.0	**57.7**	16.4	**20.9**
10th	7.0	23.8	74.2	5.2	7.7	1.8	1.7	44.5	1.7	14.1
50th	**16.8**	**57.8**	**88.7**	**6.2**	**13.5**	**3.4**	**4.2**	58.0	**15.9**	21.0
90th	31.0	121.8	95.5	7.3	23.5	5.9	9.8	68.4	29.4	29.9
N	32	60	25	65	65	65	65	65	65	65
Men, 3										
Mean	20.5	67.6	81.8	**5.8**	15.6	3.9	5.5	**61.4**	12.3	20.8
10th	10.5	21.5	68.7	4.6	7.0	2.2	1.6	47.5	1.3	12.6
50th	**19.0**	**62.0**	**83.8**	5.8	**14.1**	**3.7**	**5.1**	63.2	**11.5**	**20.1**
90th	31.0	118.5	90.1	7.2	27.2	5.5	10.6	75.9	24.6	30.0
N	25	41	14	46	46	46	46	46	46	46
Women, 1										
Mean	17.9	83.8	87.8	6.5	12.7	3.2	3.8	**54.4**	20.1	**21.7**
10th	2.5	46.8	78.7	5.3	7.0	1.8	1.3	43.6	9.5	15.0
50th	**11.3**	**72.8**	**89.6**	**6.6**	**11.6**	**2.9**	**3.4**	54.8	**19.2**	21.5
90th	43.7	124.8	94.9	7.4	19.3	4.6	6.4	64.0	29.5	29.0
N	72	100	58	104	104	104	104	104	104	104
Women, 2										
Mean	19.1	87.2	86.3	6.3	13.9	**3.2**	4.0	**49.8**	25.5	**20.7**
10th	5.2	48.7	77.5	5.1	7.5	1.8	1.3	35.0	9.0	14.3
50th	**14.5**	**69.5**	**88.2**	**6.5**	**12.5**	3.2	**3.5**	49.3	**25.0**	21.0
90th	41.5	150.3	94.7	7.5	23.1	4.6	6.9	66.2	43.8	26.8
N	73	123	50	132	132	132	132	132	132	132
Women, 3										
Mean	21.3	81.5	81.7	6.1	15.2	**3.0**	4.3	**53.4**	**21.7**	**20.6**
10th	5.0	46.7	70.8	4.5	6.0	1.5	1.2	39.7	7.7	12.9
50th	**17.8**	**69.8**	**83.2**	**6.3**	**12.8**	2.8	**3.8**	51.8	20.8	20.8
90th	46.8	136.8	94.6	7.4	27.3	4.7	7.2	69.6	37.5	29.9
N	40	66	31	70	70	70	70	70	70	70

Age group 1 = 40-54 years; age group 2 = 55-69 years; age group 3 = 70-91 years; REM refers to rapid eye movement sleep; Arousal Index, number of arousals per hour of sleep; Awake Index, number of awakenings per hour of sleep.

Table 4—Coefficients from Multivariable Regressions of Sleep Parameters

Dependent Variable	Constant	Age (for each 10-year increase from mean age)	Sex (for woman = 1)	BMI (for each 5-unit increase from mean BMI)	Age x Sex (change for woman with 10-year increase over mean age)
Sleep latency	18.9**	0.7	0.4	0.2	NS
REM latency	74.0**	-0.6	10.2*	-6.2	NS
Sleep Efficiency	85.2**	-1.6**	0.3	-1.0	NS
Sleep Time	6.0**	-0.1*	0.3**	0.0	NS
Arousal Index	15.2**	0.8*	-1.4*	-0.4	NS
Awakening Index	3.8**	0.0	-0.6**	-0.2	NS
Stage 1, %	5.0**	0.3*	-1.1**	0.2	NS
Stage 2, %	58.2**	1.7*	-6.0**	0.0	-1.9*
Stage 3/4, % (SWS)	16.1**	-1.9*	6.7**	-1.2	2.4**
Stage REM, %	20.7**	-0.4	0.4	1.1*	NS

* $P < .05$
** $P < .01$
BMI refers to body mass index; NS, interaction term not included in model because it was not statistically significant; REM, rapid-eye-movement sleep; SWS, slow-wave sleep.

A possible weakness of our data is exclusion of certain sleep parameters for analysis due to quality issues. We do not feel that this has introduced any bias into the data because we have seen no significant changes to the sleep parameters when they were included. Additionally, previous work from our group has shown little effect of host characteristics on study quality other than sensor loss associated with increasing BMI.[19] Our population had normal BMIs.

The data for this study were derived from a large pool of well-characterized adults created by excluding those with symptoms that we felt could interfere with sleep, rather than simply excluding by disease categories. Because there is no literature to suggest that well-controlled chronic illnesses impact negatively on sleep, our criteria allowed the inclusion of subjects who may be diabetic or have experienced events such as a myocardial infarction or hypertension but who are well controlled on treatment and symptom free. We believe this is a more meaningful 'normative' sample among subjects over 40 years of age as opposed to a 'super-normal' group of entirely healthy persons. We were also able to exclude those subjects who used substances that could interfere with sleep such as alcohol and caffeine within 4 hours of the study. We feel, therefore, that the reported sleep parameters in this large sample can be considered representative of 'normal' sleep in the healthy adult US population over age 40 years and may provide useful normative data regarding sleep and its changes across age, sex, and perhaps race.

Table 5a—Comparison of Epworth Sleepiness Scale Scores in Men

	No. Studied	ESS score ≥ 10	ESS score < 10
Age	155	63.1 (10.8)	59.6 (11.8)
BMI	155	25.3 (2.5)	25.8 (2.6)
Habitual Snorers, %	155	34.9	23.2
Answered at least *often* not sleep enough*, %	153	16.7	6.3
Weekday Sleep*, h	155	6.7 (0.9)	7.2 (1.1)
Weekend Sleep*, h	154	7.2 (1.0)	7.8 (1.1)
RDI	155	17.8 (6.4)	17.2 (6.4)
RDI 4%	155	1.6 (1.2)	1.3 (1.1)
Mean Sleep Latency, min	86	18.3 (18.7)	19.6 (12.7)
REM Latency, min	143	68.8 (41.5)	75.1 (49.1)
Sleep Efficiency, %	57	85.6 (7.6)	84.8 (7.2)
Sleep time, h	155	6.0 (0.8)	6.0 (1.0)
Arousal Index	155	15.3 (7.0)	15.4 (6.4)
Awake Index	155	3.8 (1.2)	3.7 (1.6)
Stage 1, %	155	5.1 (3.3)	5.1 (3.1)
Stage 2, %	155	58.7 (11.3)	58.2 (10.4)
SWS, %	155	15.1 (11.7)	15.9 (10.0)
Stage REM, %	155	21.0 (6.2)	20.8 (5.8)

Data are presented as mean (SD) unless otherwise noted.
* $P < .05$ for comparison of 2 groups.
ESS refers to Epworth Sleepiness Scale; BMI, body mass index, in kg/m^2; RDI, respiratory disturbance index**;** RDI 4%, RDI associated with a 4% decrease in oxygen saturation; SWS, slow-wave sleep; REM, rapid-eye-movement sleep.

Table 5b—Comparison of Epworth Sleepiness Scale Scores in Women

	No. Studied	ESS score ≥ 10	ESS score < 10
Age	296	59.3 (9.9)	59.7 (11.5)
BMI	296	25.2 (2.7)	24.5 (3.0)
Habitual Snorers, %	296	21.5%	7.8%
Answered at least *often* not sleep enough*, %	294	16.9%	7.9%
Weekday Sleep, h	293	7.0 (1.2)	7.4 (0.9)
Weekend Sleep, h	295	7.6 (1.3)	7.9 (1.0)
RDI	296	18.0 (6.5)	16.3 (6.8)
RDI 4%	296	1.3 (1.2)	1.1 (1.1)
Mean Sleep Latency*, min	179	14.9 (13.5)	20.6 (20.0)
REM Latency*, min	281	75.1 (41.0)	87.3 (43.8)
Sleep Efficiency, %	134	87.7 (6.9)	85.6 (8.5)
Sleep time, h	296	6.5 (0.9)	6.3 (1.0)
Arousal Index	296	12.4 (5.1)	14.0 (6.9)
Awake Index	296	3.0 (1.0)	3.2 (1.2)
Stage 1, %	296	3.5 (2.0)	4.1 (2.5)
Stage 2, %	296	52.4 (11.5)	52.0 (10.7)
SWS, %	296	22.9 (11.0)	22.9 (12.3)
Stage REM, %	296	21.2 (5.1)	21.0 (5.7)

Data are presented as mean (SD) unless otherwise noted.
* $P < .05$ for comparison of 2 groups.
ESS refers to Epworth Sleepiness Scale; BMI, body mass index, in kg/m^2; RDI, respiratory disturbance index**;** RDI 4%, RDI associated with a 4% decrease in oxygen saturation; SWS, slow-wave sleep; REM, rapid-eye-movement sleep.

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