Trends in the Prevalence of Short Sleepers in the USA: 1975–2006

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Study Objectives: To determine (1) whether short sleep has increased over 31 years; (2) whether trends in short sleep differed by employment status; (3) which sociodemographic factors predict short sleep; and (4) how short sleepers spend their time.
Design: Time diaries from eight national studies conducted between 1975 and 2006.
Patients or Participants: U.S. adults ≥ 18 years.
Measurements and Results: Short sleepers were defined as those reporting < 6 hours of sleep in their time diary. Unadjusted percentages of short sleepers ranged from 7.6% in 1975 to 9.3% in 2006. The 1998-99 study had the highest odds of short sleep. The odds ratio for the 31-year period predicting short sleep was 1.14 (95% CI: 0.92, 1.50, P = 0.22), adjusting for age, sex, education, employment, race, marital status, income, and day of week. When stratified by employment, there was a significant increase for full-time workers (P = 0.05), who represented over 50% of participants in all studies, and a significant decrease for students (P = 0.01), who represented < 5% of participants. The odds of short sleep were lower for women, those ≥ 65 years, Asians, Hispanics, and married people. The odds were higher for full-time workers, those with some college education, and African Americans. Short sleepers in all employment categories spent more time on personal activities. Short sleepers who were full- and part-time workers spent much more time working.
Conclusions: Based on time diaries, the increase in the odds of short sleep over the past 31 years was significant among full-time workers only. Work hours are much longer for full-time workers sleeping < 6 hours.
Keywords: Time diary, short sleep, activity, work, secular trend
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MANY HAVE SPECULATED THAT HABITUAL SLEEP PATTERNS HAVE CHANGED OVER THE PAST SEVERAL DECADES IN THE U.S. IN PARTICULAR, SOME EVIDENCE suggests that the proportion of short sleepers has increased over the past 30-40 years, a period when the prevalence of chronic diseases that may be linked to sleep, such as diabetes and obesity, have increased dramatically. In 1959–1960, the American Cancer Society survey of more than one million adults found that 2% of their sample reported sleeping < 6 h per night.[1] Five years later, a study of 7000 adults in Alameda County, California reported that 14% of their sample obtained ≤ 6 h sleep.[2] In a second large American Cancer Society survey in 1982, approximately 20% of adults reported ≤ 6 h of sleep.[3] Finally, a short report from the National Health Interview Survey indicated that the percentage of adults reporting sleeping ≤ 6 h increased between 1985 and 2004 for both men and women and averaged nearly 30% for those between 30 and 64 years of age in 2004.[4] Taken together, these surveys suggest an approximate doubling of the proportion of short sleepers over the past 4 decades, from about 15% to 30%. However, these studies do not share consistent methodologies, both with respect to the nature of the study population (national versus local and volunteer versus representative) and the survey questions. There is a need to confirm that there has indeed been an increase in the proportion of short sleepers in recent decades.

Numerous epidemiologic and laboratory studies have demonstrated that short sleep durations are associated with increased risk of mortality and morbidity, such as diabetes, obesity, and hypertension. Therefore, it is important to identify factors associated with short sleep durations. Several previous studies reported that unmarried persons and those of lower socioeconomic status were more likely to be short sleepers.[5-8] We expand upon this work by exploring sociodemographic predictors using data from several studies that span a 31-year time period.

Our goal was to examine secular trends in short sleep using data from several different studies over a 31-year period that shared a similar methodology for determining how people spend their time: 24-h time diaries. One explanation for why there might be an increase in the number of short sleepers since 1975 would be changes in the labor force. Specifically, the participation of women in the labor force and the proportion of persons working extended hours have both increased over this time period.[9] In this project, we examine time diaries collected in 8 different national U.S. studies between 1975 and 2006. Time diaries provide detailed information when each activity stops and starts over a single 24-h period and avoid emphasizing any specific activity; however, it is important to note that activities included in the "sleep" category include waking activities such as resting and getting ready. There are 4 aims to this analysis: (1) to examine whether the proportion of short sleepers over the past 31 years has changed; (2) to determine whether the proportion of short sleepers has changed within different employment status categories; (3) to examine which sociodemographic factors predict short sleep and whether these associations have

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changed over the past 31 years; and (4) to determine how short sleepers in each employment category spend their greater wake time.

METHODS

We combined data from 8 different studies, including the Americans' Use of Time Series (1975, 1985, and 1998-99), the Environmental Protection Agency Time Use Study (1992-94), and the American Time Use Survey (2003, 2004, 2005, 2006). All are population-based samples that include at least one 24-h time diary and sociodemographic information.

Time diaries collect information concerning the timing and duration of various activities over a 24-h period. The use of time diaries is open-ended, so there is no emphasis on any particular activity that could bias responses, such as asking how many hours per day someone usually spends watching television.[10,11] Studies that ask respondents to estimate time spent doing specific activities, such as working or shopping, are subject to exaggeration compared to time diaries.[11,12] If sleep duration is also subject to exaggeration or understatement, the time diary approach may provide a better method for measuring daily behavior than a single survey question.

The samples for each of these studies were designed to be nationally representative. The Americans' Use of Time series started as part of a multinational time budget project and consists of several datasets, including Time Use in Economic and Social Accounts, 1975-1976; Americans' Use of Time, 1985; and Family Interaction, Social Capital, and Trends in Time Use (FISCT), 1998-1999. The respondents in the 1975 study were chosen to form a representative sample of American adults 18 years of age and older living in the coterminous U.S..[13] Spouses of the respondents were also interviewed. The original respondents and their spouses were re-interviewed 3 additional times during 1976; however, in these analyses we used only the first wave of time diaries, which were collected during personal interviews. Respondents reported time spent in activities for the 24 h (midnight to midnight) prior to the interview.

The 1985 study followed the same diary methodology that was used in the 1975 Time Use in Economic and Social Accounts study.[14,15] Respondents completed a single 24-h time diary, and the time diaries were gathered using 3 different data collection methods: mail-back, telephone, and personal interviews.[16] The data for the main (mail-back) study were collected from a sample of Americans who were first contacted by telephone, using a Waksberg-Mitofsky 2-stage random-digit dial design. Once contacted, a respondent aged 18 years or older was selected at random and given a brief interview followed by an invitation to participate. A total of 2,921 mail-back diaries were completed and returned by adults aged 18 years and over. The telephone survey consisted of a random sample of the adults who were contacted in the first phase of the random-digit dial sample, and a total of 1,210 telephone diaries were completed by this group. A separate national sample of 808 diaries was collected through in-home personal interviews.

Data collection methods in the 1998-1999 FISCT study were consistent with methods used in the 1975 and 1985 studies.[17,18] Time diaries were collected from a representative sample of 1,151 respondents aged 18 years and older. Using established time-diary procedures with computer assisted telephone interviewing (CATI), respondents were asked to complete "yesterday" time diaries detailing their activities from midnight to midnight of the previous day. Sampling involved a simple random sample of possible telephone numbers from a One Plus List-Assisted Random Digit Dial (RDD) frame and included adults aged 18 years or older residing in households with telephones in the contiguous 48 United States and the District of Columbia.

The 1992-1994 data come from a time use study conducted by the Environmental Protection Agency that involved a nationwide telephone survey in which people were asked to report all the activities they did "yesterday."[19] The target population was people in households with telephones within the 48 contiguous states; the sample was identified using the 2-stage Mitofsky-Waksberg random digit dial sample design, stratified by census regions.[20] One time diary from one adult per household was included.

The American Time Use Survey (ATUS) is sponsored by the Bureau of Labor Statistics and is conducted by the U.S. Census Bureau.[21] ATUS randomly selected individuals from a subset of the households that completed their eighth and final month interviews for the Current Population Survey (CPS). Participants were interviewed once about how they spent their time on the previous day (04:00 to 04:00) using CATI. The target population for ATUS was all non-institutionalized persons living in households in the U.S. who are at least 15 years of age, excluding active military personnel. The ATUS used a stratified, 3-stage sampling method. States are sampled approximately equally to their proportion of the national population, however, households are stratified based on demographic characteristics, including race/ethnicity, the presence and age of children, and the number of adults in adults-only households. Sampling rates vary within these strata. In the last stage of selection, an eligible person at least 15 years of age from each household is randomly selected to be the designated person for ATUS.

Variables

The variables used in these analyses include:

Short Sleeper

We calculated the number of minutes in the 24-h period spent sleeping, napping, or resting in each of the 8 studies. When a person completes a time diary, he or she may use any vocabulary to describe activities, and then study personnel assign activity codes from a fixed set of comprehensive categories. While the recent American Time Use Survey provides detailed documentation of the various words and phrases assigned to each category, most of the earlier surveys do not. Some of the surveys combine sleeping, resting, and napping activities, so that one cannot consistently distinguish among them. Therefore we combine them here. We focus our analysis on short sleepers, which we defined as those who reported < 360 minutes (6 total h) per day of sleep, nap, or rest, because the physiologic sleep duration of these individuals could not be > 6 hours. Taken together, epidemiologic studies suggest that < 6 h is associated with increased morbidity risk, while the evidence for 6–6.5 h having adverse health effects is less consistent. Therefore, in the present study, individuals reporting < 6 h of sleep were considered "short sleepers" similar to definitions used in survey studies that assessed actual or perceived sleep hours.

Employment Status

Each study provided an employment status for the participants, and the following 5 categories were used: full-time worker, part-time worker, student, retired/homemaker; unemployed. Some studies did not distinguish between retired and homemakers, so they are combined here.

Study

A dummy variable for each of the 8 studies was created.

Year

Year was modeled as a linear term and centered at 1975.

Day of week

Indicator variables for the day of week that the diary was completed were created.

Age

Age was available in all studies. We created 6 age categories: 18–24 years, 25–34 years, 35–44 years, 45–54 years, 55–64 years, and ≥ 65 years.

Sex

Sex of the respondent was available in all studies.

Education

Education was available in all studies. The following 4 categories were used: < 12th grade, high school graduate, some college, and college degree or higher.

Race

Race was available for 7 of the 8 studies. The 1985 data did not include race and is therefore excluded from analyses that include race. The 1998 study had 4 racial categories: "white," "African American," "Asian," and "other." They also asked if respondents were of Hispanic descent. We collapsed the more detailed race categories in the other studies into the following 5 categories in our analyses: "white," "African American," "Asian," "Hispanic," and "other."

Income Quartile

Information on household income was available for 7 of the 8 studies. The 1992-94 data did not include income and is therefore excluded from analyses that include income. Income was divided into quartiles within each study. Analyses using categories of inflation-adjusted dollars gave similar results.

Marital Status

Marital status was available for 7 of the 8 studies. The 1992-94 data did not include marital status and is therefore excluded from analyses that include marital status. The following 4 categories are used in these analyses: "married," "single," "divorced/separated," and "widowed."

Daily Activities

Daily activities from the time diaries were divided into the categories below. These are aggregate categories often used in time diary studies. For each we calculated the total amount of time (in minutes) spent on each activity during the diary day.

Work. Includes paid work, either part-time or full-time, or looking for work.

Commute. This includes travel time to and from work.

Household. Includes child care, house cleaning, and maintenance.

Shopping. Includes grocery and household shopping, medical care, financial services, auto services and other services.

Personal. Includes washing, dressing, meals at home, and home medical care, but not sleep, which is generally included in the personal time category in time diary studies.

Education. Includes taking classes, doing homework and or administrative activities associated with education.

Organizational. Includes volunteer work, religious practice, professional or union activity, and political work.

Social. Includes socializing, attending sporting events, going to the movies, theaters, museums, and restaurants.

Sports/Active Leisure. Includes participating in sporting events, exercising, outdoor activities, hobbies, and games.

Passive Leisure. Includes listening to the radio, watching television, reading, and playing computer games.

Statistical Analysis

Means and proportions of the sociodemographic variables were calculated for each study. To address the question of secular changes in short sleep, we used 2 logistic regression models to predict short sleep and the key independent variables are the indicator variables for each study. Model 1 included the following covariates: age, sex, education, employment status, and day of week for all studies combined. Model 2 added income quartile, marital status, and race to Model 1; however addition of these variables eliminates 2 studies from the analyses: 1985 and 1992-94. We reran these models replacing the indicator variables for each study with a single continuous variable for study year to determine whether there is a significant secular trend.

We also examined whether the proportion of short sleepers has changed within employment status categories by stratifying the first logistic regression model described above by the 5 employment categories. To determine whether the association between short sleep and the different sociodemographic predictors has changed over time, we created interaction terms between the linear term for year and each sociodemographic variable.

Finally, to address the question concerning how short sleepers were spending their greater wake time, linear regression models stratified by employment status were estimated to predict the number of minutes spent in each of the 10 daily activity categories with an indicator variable for short sleepers, and adjusting for study, age, sex, education, and day of the week. We report the coefficient for the short sleeper indicator variable, which represents the mean difference in minutes for short sleepers versus others for each of the activities.

All studies provided sample weights for analysis. For 1975, the sample weight adjusts the sample to match 1975 census parameters for age, sex, education, and urbanicity as well as account for bias due to including husband and wife as separate respondents. In the 1985 data, the sample weight adjusts the sample to match 1985 census data for sex and full-time employment and it creates equal representation for each day of the week. The sample weight in the 1992-94 data adjusts for the oversample of weekend interviews, multiple telephone lines, differential response rates by census region, the undersampling of adults in households with children and adjusts for day of the week. The sample weight in the 1998-99 data adjusts for the unequal number of interviews collected on each of the days of week, adjusts the sample distribution to match the 1996 Current Population Survey on sex, age, education, race, and census region, and adjust for the probability of selection due to the number of non-business telephone numbers and the number of adults in the household. The ATUS (2003-2006) sample weights

Table 1—Sociodemographic characteristics and proportion of short sleepers for each study

	Year of Study							
	1975	**1985**	**1992-94**	**1998-99**	**2003**	**2004**	**2005**	**2006**
n	**2,235**	**4,939**	**7,106**	**1,096**	**19,759**	**13,318**	**12,419**	**12,200**
Age (mean ± SD; years)	43±18	50±24	43±16	45±17	45±17	46±17	46±17	46±17
Sex (% female)	56	51	54	52	52	52	52	52
Race								
White (%)	88.8	n/a	79.6	79.9	72.6	72.7	71.5	71.7
African American (%)	8.4	n/a	8.9	11.6	11.0	10.8	11.1	11.6
Hispanic	2.2	n/a	8.3	6.3	11.8	12.0	12.5	12.9
Asian	0.4	n/a	2.0	0.8	2.8	2.5	2.8	3.2
Other (%)	0.3	n/a	1.3	1.5	1.8	2.0	2.1	0.7
Education								
≤11th grade (%)	31.7	17.7	10.4	16.2	13.8	12.6	13.0	12.5
High school graduate (%)	36.5	42.8	36.3	34.0	33.8	34.4	34.2	33.9
Some college (%)	17.6	17.2	25.1	27.2	26.5	25.9	26.1	26.7
College graduate (%)	14.2	22.2	28.2	22.6	25.9	27.2	26.6	27.0
Employment								
Full-time (%)	53.3	60.2	57.4	59.3	52.8	52.5	53.8	53.7
Part-time (%)	2.5	9.7	11.4	10.8	13.7	13.7	13.5	13.3
Student (%)	4.3	3.8	3.0	2.8	3.1	2.9	2.5	2.8
Retired or homemaker (%)	35.0	22.9	20.0	20.0	26.8	27.4	27.1	26.9
Unemployed (%)	5.0	3.3	8.2	7.1	3.7	3.5	3.1	3.4
Marital status								
Married	61.4	64.0	n/a	59.5	58.2	59.2	58.3	58.6
Single	15.7	20.0	n/a	20.6	24.3	23.7	24.0	24.1
Divorced/Separated	11.6	9.2	n/a	12.9	11.2	11.2	11.7	11.4
Widowed	11.4	6.9	n/a	7.1	6.3	5.9	6.0	5.9
Short sleepers, <6 h (%)	7.6	9.9	7.5	11.8	8.7	8.8	8.3	9.3

n/a – not available
Separate sample weights were used for each study.

compensate for aspects of the sampling and data collection process, including stratified random sampling, uneven sampling across the days of the week, and different response rates across demographic groups and days of the week. In our analyses, all sample weights had a mean of 1.0 within each study. For the 1975 and the ATUS 2003-2006 data, sample weights were transformed so that the mean was equal to 1.0 within each study year. The sample weights provided by the 1985, 1992, and 1998 studies already had a mean of 1.0 and were not altered.

For all analyses, the following groups were the reference category for that variable: the 1975 study, aged 18-24 years, white race, college degree or higher, highest income quartile, full-time employment, and Monday. We used the Wald test to test for overall significance of each categorical variable, and if significant, we conducted pair-wise comparisons. The robust variance estimator was used in regression models to calculate confidence intervals and P values. All analyses use the transformed sample weights. Statistical analyses were performed using Stata 9.2 (StataCorp, College Station, TX).

RESULTS

Table 1 provides a description of the demographics for each study. Several sociodemographic factors have changed over the eight studies (Table 1). In particular, the proportions of nonwhites and of those with some college education or higher have increased from 1975 to 2006, whereas the proportion of unemployed has decreased from 1975 to 2006. The unadjusted proportion of short sleepers was 7.6% in the 1975 sample and 9.3% in the 2006 sample (Table 1). The 1998 sample had the highest unadjusted percentage of short sleepers. Table 2 presents the unadjusted mean time spent in minutes in each of the daily activity categories for each study.

Figure 1 presents the odds ratios predicting short sleep for each study relative to 1975, after adjustment for age, sex, education, employment status and day of the week. The overall effect of study was significant (7 degree of freedom Wald test, $\chi^2 = 29.2$, $P = 0.0001$). There were several significant pairwise comparisons between individual studies for the odds of short sleep ($P < 0.05$). The 1985 and 1998-99 studies were different from the 1975 study, and the 1985 study also differed from the 1992-94 and 2003-2005 studies. The 1992-94 study differed from all other studies except 1975 and the 1998-99 study differed from all other studies except 1985. The 2003, 2004, and 2005 studies did not differ from one another; however, the 2006 study differed from 2005. We also analyzed year as a continuous predictor of short sleep and the odds ratio for the

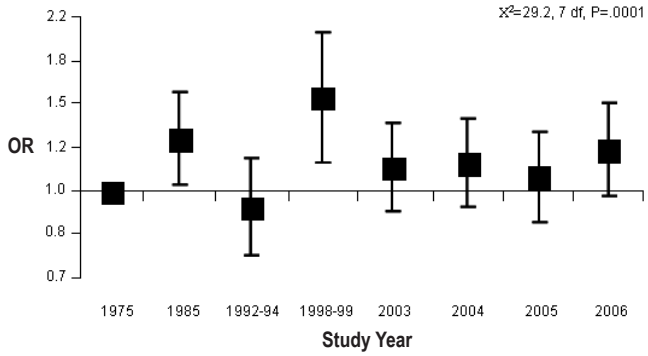

Figure 1—Odds ratios predicting short sleep (< 6 h) by year of study from a logistic regression model adjusted for age, sex, education, employment status and day of week. Error bars represent 95% confidence intervals.

31-year trend was 1.08 (95% CI: 0.94, 1.24, P = 0.29). When we added income, race and marital status to the model, which eliminated the 2 studies that lacked those data, the overall significance test of the study variable remained significant (5 degree of freedom Wald test, $\chi^2 = 16.2$, P = 0.006). The pairwise analysis indicated that the 1975 study was significantly different from 1998-99 and 2006, and that 1998-99 was also different than 2003, 2004, and 2005. Finally the 2006 study was significantly different than 2003 and 2005. The odds ratio for year as a continuous predictor of short sleep was 1.14 (95% CI: 0.92, 1.41, P = 0.22) for the entire 31-year period. Since the 1998-99 study was an outlier for the proportion of short sleepers, we carried out a sensitivity analysis excluding the 1998-99 data. The odds ratio for the linear trend in study year for all of the other studies adjusting for age, sex, education, employment status and day of the week was 1.09 over the 31 years (95% CI: 0.95, 1.26, P = 0.22). When we added income, race and marital status to this model, the odds ratio for the 31-year trend was 1.19 (95% CI: 0.95, 1.49, P = 0.12). Finally, we examined 2 alternative definitions of short sleep: < 330 min (5.5 h) and < 390 min (6.5 h). The 31-year increase in short sleep was slightly larger for < 5.5 h (OR in the fully adjusted model was 1.20, 95% CI: 0.92, 1.56) while for < 6.5 h, the effect of time was greatly reduced (OR in the fully adjusted model was 1.11, 95% CI: 0.94, 1.32). These results suggest that the secular increase in short sleep may be due to increases in extremely short sleep durations.

We stratified by employment status to examine the odds of short sleep over the 31-year period for each employment group separately, and the associations did vary by employment status (Figure 2). For full-time workers, the odds for short sleep differed significantly between studies (7 degree of freedom Wald test, $\chi^2 = 28.8$, P = 0.0002). The odds ratio for the trend over 31 years was 1.19 (95% CI: 1.00, 1.42, P = 0.05) among the full-time workers. Among students, the odds for short sleep differed significantly between studies (7 degree of freedom Wald test, $\chi^2 = 20.2$, P = 0.005), and the odds ratio for the trend over 31 years was 0.37 (95% CI: 0.17, 0.81, P = 0.01). There were no significant associations between short sleep and study for part-time workers, retired/homemakers or the unemployed. Adding income, marital status, and race to the models produced similar results.

Figure 3 presents the odds ratios predicting short sleep for each of the sociodemographic variables, which were all included in a single regression model. Almost all demonstrated a significant association. The oldest age category (≥ 65 years) was associated with a significantly reduced odds of being a short sleeper compared to all other age groups, and 45-54 year olds were more likely to be short sleepers compared to those aged 25-34 years, 35-44 years, and 55-64 years. Women were less likely to be short sleepers than men, and those with some college education were significantly more likely to be short sleepers than those with less or more education. Part-time workers, students, retired/homemakers and the unemployed did not differ from each other, but all were significantly less likely to be short sleepers than full-time workers. African Americans were more likely to be short sleepers than whites, Asians, and Hispanics; and Asians and Hispanics were less likely to be short sleepers

Table 2—Mean (± SD) time spent in each daily activity by study

	Year of Study							
	1975	1985	1992-94	1998-99	2003	2004	2005	2006
Daily activities (minutes)								
Work	219 ± 274	237 ± 281	244 ± 291	251 ± 290	231 ± 281	231 ± 279	232 ± 279	236 ± 283
Household	152 ± 165	150 ± 161	134 ± 165	160 ± 173	156 ± 172	154 ± 170	155 ± 169	151 ± 168
Shopping	43 ± 71	51 ± 84	50 ± 93	50 ± 90	47 ± 80	47 ± 82	47 ± 79	47 ± 81
Personal (excluding sleep)	156 ± 141	161 ± 104	139 ± 108	156 ± 119	140 ± 109	143 ± 109	141 ± 106	139 ± 106
Sleep	509 ± 134	484 ± 123	496 ± 123	484 ± 125	509 ± 132	507 ± 133	510 ± 134	510 ± 135
Education	21 ± 92	28 ± 88	21 ± 99	21 ± 86	16 ± 83	16 ± 81	15 ± 77	16 ± 75
Organizational	24 ± 71	19 ± 65	18 ± 66	18 ± 65	19 ± 69	19 ± 67	18 ± 64	18 ± 63
Social	69 ± 114	65 ± 120	67 ± 134	60 ± 122	63 ± 115	60 ± 111	60 ± 111	61 ± 113
Sports/active leisure	42 ± 98	46 ± 99	45 ± 112	38 ± 90	20 ± 65	20 ± 66	20 ± 64	19 ± 61
Passive leisure	206 ± 161	199 ± 159	225 ± 185	201 ± 196	220 ± 188	225 ± 190	222 ± 189	221 ± 188
Commute	18 ± 31	23 ± 44	22 ± 38	27 ± 42	18 ± 37	18 ± 35	18 ± 36	19 ± 36

Note: The means for each activity category include individuals with zero activity in that category on the diary day. Separate sample weights were used for each study.

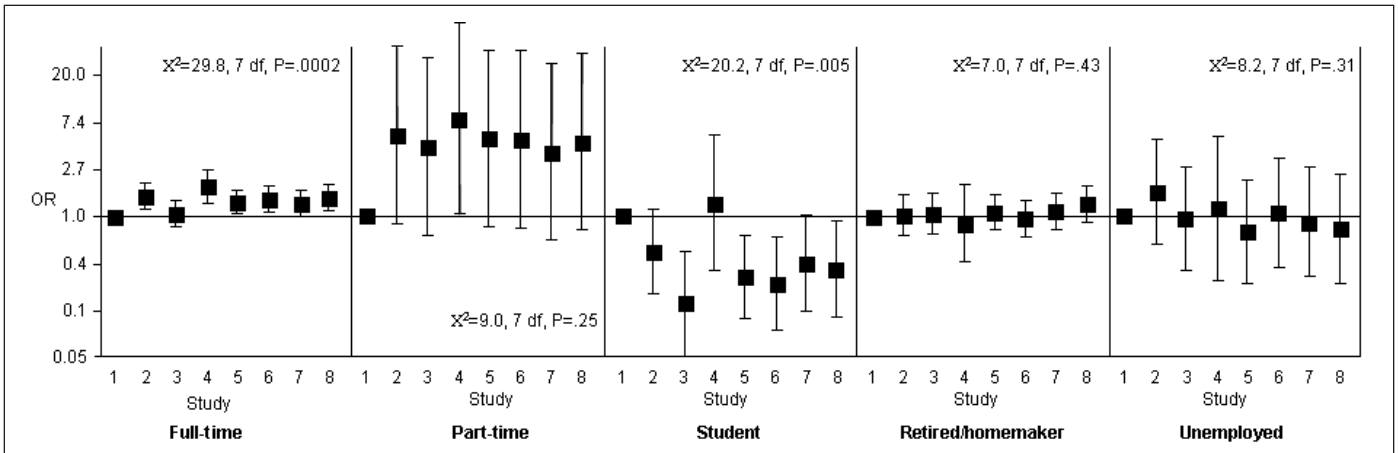

Figure 2—Odds ratios predicting short sleep (< 6 h) stratified by employment status adjusted for age, sex, education & day of week for each subsequent study compared to the 1975 study. Error bars represent 95% confidence intervals. 1 = 1975; 2 = 1985; 3 = 1992-4; 4 = 1998-99; 5 = 2003; 6 = 2004; 7 = 2005; 8 = 2006.

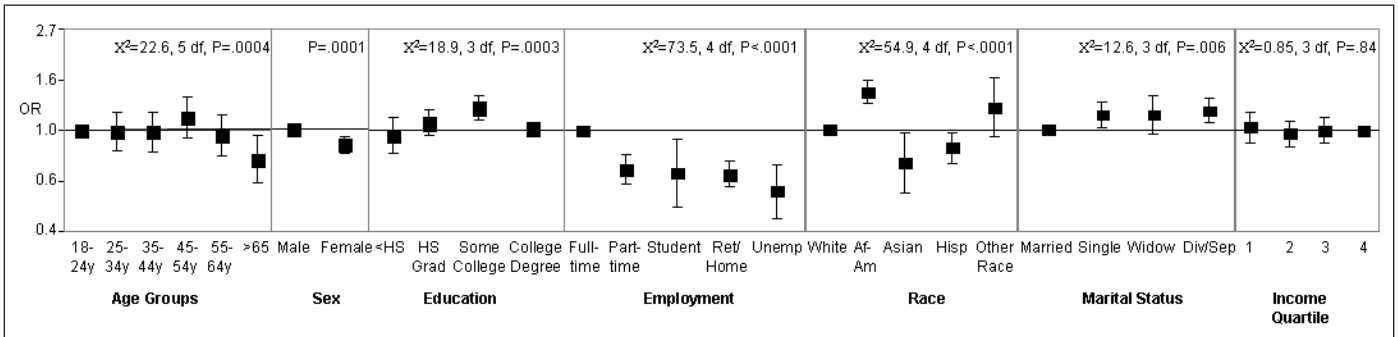

Figure 3—Odds ratios predicting short sleep (< 6h) for each sociodemographic variable from a single logistic regression model adjusting for each sociodemographic variable in figure as well as year of study and day of week. [Note data from 1985 and 1992-94 were omitted due to missing income, marital status, or race data.] Error bars represent 95% confidence intervals.

than both whites and those in the other race category. Single and divorced/separated people were more likely to be short sleepers than married people. There were no significant associations between income level and short sleep. When we estimated a regression model that included only those variables available in all studies (age, sex, education, and employment status), the association between these sociodemographic predictors and short sleep were similar to those presented in Figure 3.

To determine whether the association between the sociodemographic variables and short sleep changed over the 31-year period, we examined interaction terms between year as a linear term and each sociodemographic variable. The only significant interaction by year was for employment status (4 degree of freedom Wald test, $\chi^2 = 11.0$, P = 0.03). The trend in odds of short sleep increased over 31 years for full-time workers, while the odds of short sleep decreased over 31 years for students.

Table 3 presents the average difference in time spent in each of the activity categories for the short sleeper group compared to longer sleepers by employment status. The personal activities category (excluding sleep) was the only activity that was significantly greater among the short sleepers for all employment groups and the difference ranged from 30 to 91 minutes. Work time and commute time was only significantly greater among short sleepers who were employed either full-time or part-time. The difference in work time was large: 2.4 h for full-time workers and 1.3 h for part-time workers. For students, short sleepers spent > 2 h more on average participating in educational activities. Short-sleepers who were part-time workers also spent significantly more time in educational activities. Short sleepers in all employment groups except the unemployed spent more time on social activities. Only short sleepers who were retired or homemakers spent more time on passive leisure, on average almost 2 hours more than non-short sleepers. Sports and active leisure were significantly greater among short sleepers who were full-time workers, part-time workers and retired/homemakers, although the difference was only 8-15 minutes.

DISCUSSION

Our results indicate that, based on time use diaries, the odds of being a short sleeper have not increased significantly over the past 31 years when all employment categories are combined and the data are adjusted for sociodemographic factors including age, education, employment status, race, income and marital status. Most of the individual studies in our analyses had a higher proportion of short sleepers compared to 1975, but the highest proportion of short sleepers was observed in the 1998-99 data, which had the smallest sample size. Our results indicate that the odds of being a short sleeper based on time

Table 3—Mean difference in minutes (95% CI) spent in each daily activity category for short sleepers (< 6 h) compared to others, from adjusted† regression models stratified by employment status.

Daily Activity Predicted	Full-time Workers	Part-time Workers	Students	Retired/ Homemaker	Unemployed
Work	+143 (132, 154)	+78 (51, 105)	+6 (−11, 23)	+4 (−1, 9)	+22 (−6, 50)
Household	+9 (3, 15)	+13 (−5, 31)	−16 (−43, 11)	+23 (8, 38)	+32 (−10, 74)
Shopping	−2 (−5, 1)	+2 (−6, 11)	+1 (−16, 18)	+8 (1, 15)	+16 (-3, 35)
Personal (sleep excluded)	+30 (24, 36)	+53 (28, 79)	+42 (13, 71)	+74 (60, 89)	+91 (40, 142)
Education	+3 (1, 5)	+42 (21, 63)	+130 (65, 196)	+2 (−2, 6)	+3 (−9, 16)
Organizational	+6 (3, 8)	+1 (−5, 6)	+7 (−10, 24)	+8 (1, 15)	+16 (−2, 34)
Social	+22 (17, 27)	+25 (9, 40)	+76 (35, 118)	+19 (9, 29)	+32 (−3, 66)
Sports/Active Leisure	+8 (4, 11)	+15 (5, 25)	+5 (−13, 23)	+11 (3, 19)	+32 (−2, 66)
Passive Leisure	−4 (-11, 3)	+16 (-4, 36)	+13 (-35, 61)	+118 (97, 139)	+26 (−24, 76)
Commute	+10 (8, 12)	+7 (3, 11)	+3 (−2, 8)	+0.1 (−0.3, 0.5)	+14 (−1, 29)

† Covariates included years beyond 1975, age, sex, education, and day of week.

diaries has increased significantly among full-time workers over the past 31 years after adjustment for sociodemographic factors including age, education, employment status, race, income, and marital status. Of note, the proportions of full-time workers did not increase over time in these samples and represented more than 50% of all participants in all studies. The odds of short sleep did not change significantly over the 31-year period for part-time workers, retired/homemakers, or the unemployed; and the odds actually decreased for students who represented less than 5% of the participants. Since we included several sociodemographic variables as covariates in the models, our estimated increase in short sleepers in the U.S. was not due to changes in the age, gender, racial, employment status, or socioeconomic composition of the population.

In addition, the overall increase in short sleep observed in this pooled analysis based on time diaries is smaller than the increase suggested by aggregating the evidence from different surveys that have asked a single question about usual sleep duration. Thus, the assertion that sleep durations have declined drastically in the U.S. population in general over the past 30 years may be inaccurate, as some have previously argued.[22]

Several sociodemographic factors were associated with short sleep. The following groups were less likely to be short sleepers: women, those 65 years of age and older, Asians, Hispanics, and married people. The odds of short sleep were higher among full-time workers, those with some college, African Americans, and among single or divorced/separated individuals compared to married individuals. Income level was not associated with short sleep. Further analyses suggested that the associations between these sociodemographic factors and short sleep have remained consistent over the past 31 years. The exception is for students, as described above.

Not surprisingly, these results indicate that short sleepers who are employed spent the majority of their excess wake time working, and students who are short sleepers spent more time on educational activities. This is consistent with another study that examined sleep time in just the 2003-2005 ATUS time diary data in order to determine what activities influenced amount of sleep time.[23] Among those aged 20-64 years who worked, they found a reciprocal relationship between work time and sleep time: the more time devoted to work, the less time devoted to sleep. Our data demonstrate that full-time workers are more likely to be short sleepers than the other employment status groups and that this relationship has remained consistent over the past 31 years. These results are also similar to a previous analysis of the time diaries from 1965-1999 that found that unemployment was associated with increased likelihood of being a longer sleeper.[5] The greater time spent in sports and active leisure among the short sleepers was minimal, suggesting that short sleepers are not getting substantially more exercise than longer sleepers.

One important limitation of this study is that we cannot determine the amount of actual, physiologic sleep obtained. The activity category "sleep" in these time diary studies included activities other than physiologic sleep, including waking activities described as "getting up," "getting ready," "resting," and "daydreaming." This may partly explain why the average sleep durations in time diary studies are approximately 1 hour longer than what has been reported for national studies using self-reported sleep duration.[24,25] Furthermore, the waking activities included in the sleep activity category varied somewhat between studies. For this reason, we used a dichotomous variable of short sleep because respondents reporting < 6 h of "sleep" could not have > 6 h of physiologic sleep. However, the choice

of cut off for short sleep could lead to misclassification. For example, using a cut-off of 6 h will result in some true short sleepers being misclassified as non-short sleepers because the combination of actual sleep plus the waking activities included in the sleep category totaled > 6 hours. Therefore, the 6-h cut-off likely results in a lower percentage of short sleepers in time use studies than percentages based on self-reported sleep duration, which is why we also included results from two alternative cut offs: 5.5 h and 6.5 h. However, when we use a cut-off of 6.5 hours, those obtaining 6-6.5 h of sleep will be considered short sleepers in this analysis even though 6.5 h of sleep may be a sufficient amount for many individuals. Constructing a long sleeper category from these data would be more problematic since there would be people who recorded > 8 h of sleep and resting activities but who did not actually sleep > 8 hours. Another limitation is that due to the design of the time diary, the sleep period is a combination of the end of one night of sleep, the beginning of the second night of sleep and any intervening sleep periods during the day. This may be particularly problematic for diaries collected on Fridays and Sundays, which typically have one sleep period associated with work and one associated with a non-work day.[26] However, when we restrict our analyses to diaries collected on Monday through Thursday, we obtain similar results (data not shown). A third limitation is that due to the data available, retired people could not be distinguished from homemakers in all studies. Trends in short sleep may differ between homemakers and the retired. Another important limitation is that there is the potential for selection bias. The response rates for these studies ranged from 72% in the 1975 study,[5,16] which had the highest response rate, to 55% in the 2006 study,[21] which had the lowest response rate. If the reason for non-participation is related to short sleep, for example if the non-participants have less time available due to work or household responsibilities or they are simply too tired, then this would result in an underestimation of the prevalence of short sleep. In addition, although these studies aimed to be nationally representative, these samples may not in fact represent true national estimates. For example, the average age in the 1985 sample is higher than all the other studies, which is not consistent with the increase in median age that occurred in the U.S. population over the past 50 years.[27] Finally, some studies of trends in time use drawing on these same studies have also included a 1965 study,[5,16] but that sample is not nationally representative since a large proportion of the sample came from a single city, and there are no sample weights. Therefore we did not include it.

We are unaware of other studies that have examined secular trends in short sleep over 30 years in the U.S., but one study in Finland examined self-reported sleep duration from 9 different studies conducted between 1972 and 2005.[28] They observed a decline of approximately 18 min in average sleep duration over the 33-year period, but no significant increase in those reporting sleeping < 6 hours.[28] Furthermore, the decline in sleep duration was strongest in working-aged men. Thus, these results are similar to our analyses that also observed only a moderate change in sleep duration in full-time workers over 31 years.

Other studies have examined the correlates of short sleep. A recent analysis of the 2004-2007 data from the National Health Interview Survey in the U.S. reported that the following groups were more likely to be short sleepers (< 6 h): non-Hispanic blacks and other non-Hispanic individuals compared to non-Hispanic whites, those working more than 41 h/week compared to those working 1-34 h, and those with lower income.[7] Individuals with a college degree or higher or a high school degree were less likely to be short sleepers than those with less than a high school degree. Hale[5] reported that unmarried individuals and those with less than a college degree are more likely to be short sleepers. Data from the Whitehall II Study in the UK and the Western New York Health Study in the U.S. also indicated that unmarried individuals and those with lower socioeconomic status were more likely to be short sleepers.[6] A Finnish study reported that being widowed or divorced and being retired, unemployed or a full-time worker was associated with a greater likelihood of reporting short sleep (< 6 h).[8] We also found that African Americans and unmarried individuals were more likely to be short sleepers; however, we did not see a consistent trend with education or income. Other studies have previously reported that long work hours are associated with short sleep durations.[7,8,23,29-31] In addition, analysis of the ATUS 2003-2006 data indicated that those who worked > 8 hours on the diary day woke up 78 min earlier than those who worked less or not at all, but bedtimes did not differ between these groups.[32] Our study, however, is the first to examine comprehensively categories of daily activities to determine how short sleepers spend their increased wake time. Although short sleepers who are employed spent much more of their additional wake time working, they also spent significantly more time in personal and social activities. Some studies have suggested that working overtime is associated with negative health outcomes, such as depression, obesity, or hypertension.[29,33,34] Insufficient sleep should be explored further as a possible mediator of the association between increased work hours and poor health.

In multiple laboratory and epidemiologic studies, sleep times of less than 6 hours have been associated with disease risk, including include hypertension, heart disease, diabetes, and cancer, as well as impaired performance and memory, impaired immune function, and increased risk of accidents.[35-42] Increasing numbers of short sleepers could lead to an increase in these associated adverse health outcomes. Longer work times seem to be the most important cofactor for short sleep, which would require interventions beyond the clinical setting. While the increased odds of short sleep is relatively small even among full-time workers (OR 1.19), given the millions of full-time workers in the U.S., this increase translates into a substantial number of persons at risk of potentially deleterious consequences of short sleep.

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