Sociodemographic and Behavioral Predictors of Bed Time and Wake Time among US Adolescents Aged 15 to 17 Years

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Objective To examine bed times and wake times in US adolescents aged 15 to 17 years using time diaries to determine whether adolescent sleep has changed in recent years and what factors determine bed times and wake times.

Study design Time diary analysis using 2 national probability samples: 1981 Time Use Longitudinal Panel Study (n = 130) and 2003-2006 American Time Use Survey (n = 2978).

Results Average time in bed on school days was about 8 hours and was 1 to 2 hours longer on non-school days. Bed times and wake times were similar in 1981 and 2003-2006. Sociodemographic factors and daytime activities, specifically computer use and social activities, predicted bed time. On school days, school start time was the strongest predictor of wake time. Every hour earlier that school started, wake time was about 25 minutes earlier.

Conclusions Adolescents spent less than the recommended 9 hours in bed on school days. There is no evidence that this is a recent change in bed times and wake times, however. Although many factors influence bed time, school start time is the strongest determinant of wake time on school days. Increased computer use and earlier school days may be contributing to insufficient sleep in adolescents. *(J Pediatr 2009;154:426-30)*

A national survey of adolescents conducted by the National Sleep Foundation found that adolescents in high school reported spending an average of 7.5 hours in bed and getting an average of 7.2 hours of sleep per night.[1] However, a 6-year longitudinal study among adolescents given a 10-hour sleep opportunity suggested that adolescents need 9 hours of sleep on average.[2,3] Both experimental and observational studies have found deleterious health and behavioral consequences of shorter sleep duration in adolescents and young adults. Adequate sleep appears to be critical for improved school performance and cognitive performance.[4,5] Furthermore, one study found increased risk-taking behavior in adolescents who experienced more sleep problems.[6] Studies in young adults have found that sleep loss also can lead to impaired neurobehavioral performance, mental health, immune function, appetite regulation, and glucose metabolism.[7-10] Population-based studies also have found an association between sleep duration and obesity in adolescents.[11-13] Finally, sleep loss increased the risk of motor vehicle accidents in young adults,[14] and sleep-related crashes are more common in adults under age 25 years.[15] Traffic accidents are the leading cause of death in adolescents.[16] Thus, it is of concern if adolescents are sleeping only 7 to 7.5 hours per night.

In this study, we used a different type of national survey data—24-hour time diaries—to answer key questions about adolescent sleep, based on time spent in bed. Time diaries allow researchers to examine time spent in different daily activities. We used these data to address 2 questions about adolescent sleep behavior: (1) whether adolescent bed times and wake times have changed in recent years, and (2) what factors determine adolescent bed times and wake times.

METHODS

Samples

These data come from 2 different population-based studies in the United States. The American Time Use Survey (ATUS) is an annual Bureau of Labor Statistics survey; data are available for 2003, 2004, 2005, and 2006.[17] The ATUS sample is drawn from households included in the Current Population Survey (CPS), which measures labor force participation of the civilian noninstitutionalized population. One household member aged 15 or older was randomly selected from CPS households to participate in the ATUS. Only 1 time diary was collected from each participant. Time diaries were collected using

ATUS	American Time Use Survey	CPS	Current Population Survey

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Research for this study was supported by National Institutes of Health grant R01 HL082907-01.

The authors declare no conflicts of interest.

Submitted for publication Apr 1, 2008; last revision received Jul 22, 2008; accepted Aug 18, 2008.

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0022-3476/$ - see front matter

10.1016/j.jpeds.2008.08.035

computer-assisted telephone interviewing. Our analyses were restricted to the adolescents in the sample, respondents age 15 to 17 years.

The second sample is the Time Use Longitudinal Panel Study 1975-1981, a national 2-wave panel survey.[18] The 1975 data included only adults, but in 1981, up to 3 children from each household were eligible to participate. Each child participant was asked to complete 2 time diaries, for 1 school day and 1 non-school day. The time diaries were collected during personal interviews. Our analyses included children aged 15 to 17 years, for comparability with the ATUS sample.

Time Diaries

Both studies collected 24-hour time diaries. Time diaries provide detailed information about activities over a 24-hour period. The respondents indicated the time at which each activity started and ended.[17,19,20] Unlike a survey question about usual time spent in a particular activity (eg, "How many hours do you spend watching television?"), a time diary does not inquire about specific activities that may be perceived as more or less socially desirable. Studies that ask respondents to estimate time spent doing particular activities are more subject to response bias compared with time diaries.[17,21] Thus, time diaries are considered to measure more accurately daily behavior.

In the ATUS 2003-2006 data, the time diary began at 4 a.m. on the day before the interview and ended at 4 a.m. on the day of the interview. In the 1981 study, the time diary began at midnight on the day before the interview and ended at midnight on the day of the interview. The public-use data for both surveys include the actual times at which each activity started and ended.

Time Diary Variables

Bed time. Bed time was defined as the time at which the final evening sleep period began during the 24-hour period. Because more than 1 sleep episode may have occurred over the 24 hours, we considered the last sleep start time after 6:00 p.m. (but before 6 a.m.) to be the bed time. If the respondent indicated that he or she was asleep when the time diary began (4:00 a.m. in the ATUS or midnight in the 1981 Time Use Longitudinal Panel Study data), this was not considered a bed time, because we could not determine the true beginning of the sleep period.

Wake time. Wake time was defined as the first sleep end time that occurred after 4:00 a.m.

Inferred time in bed. We calculated the interval between average sleep start and average sleep end as the inferred time in bed. Because this includes the end of the previous night and the beginning of the following night, we cannot infer the total time asleep for a single night.

School start time. School start time was defined as the time at which the educational activity of taking a class began on the diary day. Only those adolescents who went to class on the diary day had a school start time.

Activities. We examined the following broad activity categories that were defined in the ATUS: work, child care, education, social entertainment, sports/active leisure, television watching, and computer use.

School day versus non-school day. We identified a diary as being from a school day if it indicated time spent taking a class on that day. If no such time was indicated, then the diary was considered to be from a non-school day.

Additional covariates included age, sex, race (Caucasian, African American, Asian, Hispanic, or other), and total household income. Income responses in the ATUS data were collected in 16 categories ranging from <$5 000/year to ≥$150 000/year. (The top category changed from ≥$75 000 to ≥$150 000 in 2003.) We converted the categorical income data into a single continuous variable by assigning the midpoint of each income category as income; for the top category, we used the Pareto estimate of the mean.[22] Because of inflation, we adjusted income using the Personal Consumption Expenditures Chain-Type Price Index.[23] Because the distribution of income is skewed, we used the natural log of the income in the regression analyses.

Statistical Analyses

The analysis comprised 2 parts: (1) a comparison of mean bed time, wake time, and time in bed in the 2003-2006 ATUS with the 1981 Time Use Longitudinal Panel Study sample to address our first study question, and (2) an analysis of the predictors of bed times and wake times in the ATUS only to address the second question. We created box plots depicting the median, 25th percentile, and 75th percentile by day of week for bed time, wake time, and time in bed in the 1981 Time Use Longitudinal Panel Study data and the ATUS data. Then we used regression models to predict average bed time, wake time, and time in bed while adjusting for age (centered at 15 years), race, and sex. These adjusted results allowed us to compare average bed time, wake time, and time in bed in the 2 time periods. We calculated separate models for school days and non-school days. For the 1981 Time Use Longitudinal Panel Study data, we also took into account the repeated diaries in some adolescents using the clustered sandwich estimator. Finally, we evaluated whether the bed time, wake time, and inferred time in bed differed between the 1981 Time Use Longitudinal Panel Study data and the 2003-2006 ATUS data using regression models that included a dummy variable identifying the 1981 Time Use Longitudinal Panel Study after adjusting for age, race, and sex.

The second part of our analyses involved separate linear multiple regression models that predicted bed time and wake time using only the 2003-2006 ATUS data. Our findings indicate which factors predict bed time and wake time. The outcome in each model was clock time, from 0

Table I. Descriptive statistics of respondents age 15 to 17 years from the 1981 Time Use Longitudinal Panel Study and the 2003-2006 ATUS

	1981	2003	2004	2005	2006
n	130	961	655	619	743
Age, years, mean ± SD	16.0 ± 0.8	16.0 ± 0.8	16.1 ± 0.8	16.1 ± 0.8	16.1 ± 0.8
Female	45%	50%	45%	50%	50%
Race					
Caucasian	89%	68%	67%	65%	67%
African American	5%	11%	12%	13%	10%
Asian	0%	3%	3%	4%	4%
Hispanic	5%	14%	14%	15%	17%
Other	0%	3%	4%	4%	1%
Household income*					
<$25 000	17%	20%	17%	27%	24%
$25 000-$50 000	33%	25%	27%	26%	28%
$50 000-$75 000	30%	22%	19%	13%	12%
≥$75 000	20%	33%	36%	34%	35%
ln income, mean ± SD	10.6 ± 0.6	10.9 ± 1.2	10.7 ± 1.0	10.7 ± 1.0	10.7 ± 0.9

SD, standard deviation.
*Income was adjusted for inflation.

Table II. Age-, race-, and sex-adjusted means ± standard errors of bed time, wake time, and time in bed for respondents age 15 to 17 years from the 1981 Time Use Longitudinal Panel Study and the 2003-2006 ATUS

	1981	2003	2004	2005	2006
n	130	961	655	619	743
Bed time on school days	22:21 ± 0:10	22:16 ± 0:14	22:34 ± 0:14	22:18 ± 0:16	22:18 ± 0:14
Bed time on non-school days	23:01 ± 0:24	22:39 ± 0:14	22:51 ± 0:17	22:48 ± 0:21	22:42 ± 0:15
Wake time on school days	6:32 ± 0:09	6:28 ± 0:08	6:25 ± 0:07	6:21 ± 0:06	6:31 ± 0:08
Wake time on non-school days	8:58 ± 0:21	9:39 ± 0:15	9:44 ± 0:33	9:27 ± 0:21	9:25 ± 0:19
Time in bed on school days	8:15 ± 0:11	8:13 ± 0:15	7:51 ± 0:15	8:03 ± 0:15	8:14 ± 0:16
Time in bed on non-school days	9:51 ± 0:30	10:54 ± 0:19	10:54 ± 0:42	10:46 ± 0:32	10:46 ± 0:20

to 24 hours. The predictors were sociodemographic factors (age, centered at 15 years; sex; centered natural log of household income), amount of time spent in different activities during the sample day (time spent in education, sports, television, computers, socializing, child care, and employment activities), and diary day of the week (Monday was the reference category). Each activity was centered at its mean. All analyses were performed using Stata 10.0 (StataCorp, College Station, Texas). The analyses were restricted to time diaries collected during September through November and January through April, because these are the months when school is in session; they are also the months in the 1981 Time Use Longitudinal Panel Study data were collected.

RESULTS

Sample descriptions from the 1981 Time Use Longitudinal Panel Study and the 2003-2006 ATUS are presented in Table I. The 1981 Time Use Longitudinal Panel Study sample was much smaller (n = 130) than any single ATUS sample. The age and sex distributions, but not the race distribution, were similar across all samples.

Have Adolescent Bed Times and Wake Times Changed in Recent Years?

Table II presents average bed time, wake time, and inferred time in bed on school days and non-school days in the 1981 Time Use Longitudinal Panel Study data and ATUS data (Figure). None of these differed significantly between the 2 studies ($P > .05$).

What Factors Determine Adolescent Bed Times and Wake Times in 2003-2006?

Table III (available at www.jpeds.com) presents results from the multiple regression models predicting bed time and wake time in the ATUS sample. Many factors significantly predicted bed time. Bed time was significantly later on Friday and Saturday than on weeknights, however, this weekend effect was reduced in the model because of the inclusion of daytime activities, which accounted for some of the difference by day of the week. Older age delayed bed time by about 9 minutes per year, and girls went to bed an average of 15 minutes later than boys. With a smaller representation, it appeared that African-American adolescents went to bed almost 25 minutes later than Caucasian adolescents. Each additional $25 000 of family income was associated with an approximately

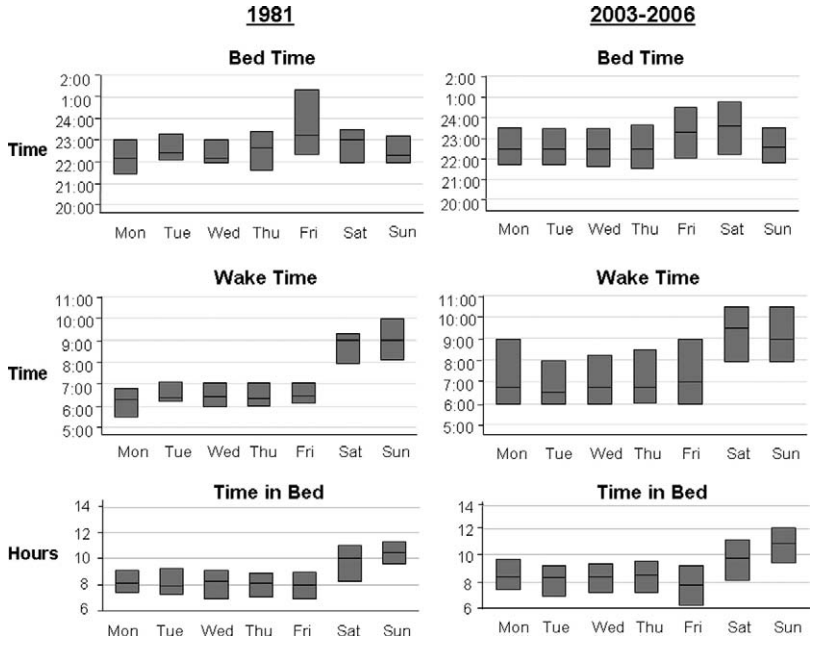

Figure. Median and interquartile range of bed time, wake time, and inferred time in bed by day of week for the 1981 Time Use Longitudinal Panel Study and the 2003-2006 ATUS. The top of the box represents the 75th percentile; the bottom of the box, the 25th percentile; the line inside the box, the 50th percentile (median). Sample weights were used.

1-hour later bed time. All of the activity categories were significantly associated with bed time, with computer use and social activities having the strongest effects. Every 1-hour increase in either of these activities delayed bed time by about 15 minutes. Television watching and working had intermediate effects, associated with a bedtime delay of 7 to 9 minutes for each hour spent on the activity. Hours spent on school, child care, and sports activities had only minimal effects.

There were fewer significant predictors of wake time than of bed time. The weekend effect was strong and significant, with later wake times on Saturdays and Sundays, even after adjusting for activities during the day. African-American and Hispanic adolescents did not differ significantly from Caucasian adolescents, but the small sample of Asian adolescents woke up an average of 45 minutes later than Caucasian adolescents. Of the daily activities, educational activity was the strongest predictor of wake time. Every additional hour of educational activity was associated with waking an average of 19 minutes earlier. Every hour of work and every hour of sports activities advanced wake time by approximately 8 to 11 minutes. Social activities had smaller effects on wake time. When we restricted these analyses to those who went to classes on the diary day and added school start time to the model, school start time was found to be a highly significant predictor of wake time ($\beta = 0.42$; 95% confidence interval = 0.26 to 0.58; $P < .001$), and none of the activities remained significant (data not shown). For every hour later that school started, wake time was delayed by approximately 25 minutes.

DISCUSSION

Our findings indicate that adolescents spend about 8 to 8.25 hours in bed on school days and 10 to 11 hours in bed on non-school days. Thus, school day bed time and wake time are not compatible with the estimated sleep need of 9 hours, and extension on non-school days may reflect a sleep debt. Bed time was only 1 hour earlier on school days compared with non-school days, but wake time was 2 hours earlier on school days. This may be due to a delay in the circadian timing of sleep onset seen in many adolescents,[2] which means that many adolescents are unable to go to bed earlier on school days to get adequate sleep. Interestingly, this bed time appears not to have changed over the past 25 years. Finally, many sociodemographic factors predict bed time, including age, sex, African-American race, and household income, but only Asian race was associated with variations in wake time. Of the activities examined, computer use and social activities were the strongest predictors of bed time, and educational activity was the strongest predictor of wake time. When only school days were examined, school start time was the strongest predictor of wake time; a 1-hour delay in school start predicted a 25-minute delay in wake time.

Because sleeping and television or computer use are mutually exclusive activities, excessive television viewing and/or computer use would necessarily limit the time available for sleep, but so would time spent on any other activity. Nonetheless, some previous studies have investigated sleep and television or computer use, perhaps because these activities are perceived as less salubrious than such activities as sports or education, or because they are newer ways to spend time. For elementary school-age children in the United States and China, increased television viewing was associated with less sleep and more sleep problems.[24,25] One longitudinal study found that excessive television viewing during adolescence predicted sleep problems in young adulthood.[26] In our

analyses, however, in the ATUS data, the effect of television watching on bed time was relatively modest, and that of computer use was stronger. Similarly, a study in Brazil found that an association between increased computer use in adolescents and decreased sleep duration and reduced subjective sleep quality.[27] Studies focused on computer use and television watching have not provided data on whether other activities also effect bed time or whether the particular impact of computer use and television watching on sleep is different than the effect of similar amounts of time devoted to other activities. Our findings show that computer use had a stronger impact on bed time than most other activities, including television watching; the exception was socializing, which exhibited a similar affect to computer use.

Our study has some limitations. First, the 1981 Time Use Longitudinal Panel Study sample size was small (n = 130), which reduced our power for comparing the 2 samples. Because in both the 1981 Time Use Longitudinal Panel Study and 2003-2006 ATUS samples, the time diary day began on one night and ended on another night, we were limited in terms of the ways in which we could quantify sleep. Thus, our analyses focused on average bed time and wake time. From average bed time and wake time, we infer time in bed, and then assume that nocturnal sleep is no longer than the amount of time in bed. Indeed, it is likely that an individual is not sleeping every minute that he or she is in bed trying to sleep. Therefore, these data strongly suggest that average sleep time on school days was less than adolescents' estimated sleep need of 9 hours. Moreover, we cannot state for certain that the increase in certain activities, such as computer use, caused a later bed time. It is possible that some adolescents spend time using a computer late at night until they are able to fall asleep. Finally, the ATUS study included greater detail on the activity descriptions compared with the 1981 Time Use Longitudinal Panel Study, which may have affected the data. Nonetheless, in both studies, sleep was included as an activity, and the time diary was completed with a study team member.

The delayed bed time and wake time found on nonschool days is consistent with the delayed circadian phase observed in many adolescents, in whom sleep naturally begins and ends later than for younger children.[2] Thus, early school start time—the main predictor of an earlier wake time among adolescents on school days—conflicts with adolescent circadian biology. The fact that these adolescents spent 2 hours less time in bed on school days is consistent with the findings of another study of 60 high school seniors that found an average 2-hour reduction in sleep on school days.[28] Another study found that students attending schools with later start times (8:37 a.m. vs 7:15 a.m.) obtained almost 1 hour more sleep.[29] In response to evidence of deleterious consequences of early school start times, several schools in Minnesota tried delaying the start time by 30 minutes or more; such a shift is not without controversy, however.[30] Nonetheless, our findings confirm that on school days, adolescents are obtaining less sleep then they are considered to need, and school start time is the factor with the greatest impact. If sleep loss is associated with impaired learning and health, then these data point to computer use, social activities, and especially school start time as the most obvious intervention points.

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Table III. Multiple regression models predicting bed time (hours) and wake time (hours) in respondents aged 15 to 17 years from the 2003-2006 ATUS

	Bed time (hours)			Wake time (hours)		
	Coefficient	**95% CI**	***P* value**	**Coefficient**	**95% CI**	***P* value**
Constant	21.43	20.36, 22.49	<.001	7.71	6.81, 8.60	<.001
Day of the week						
Monday	Reference			Reference		
Tuesday	−.09	−0.45, 0.27	.62	0.04	−0.27, 0.35	.80
Wednesday	−.08	−0.42, 0.25	.63	−0.02	−0.28, 0.24	.86
Thursday	−0.15	−0.48, 0.19	.39	0.26	−0.07, 0.58	.12
Friday	0.53	0.14, 0.91	.008	0.12	−0.30, 0.53	.59
Saturday	0.62	0.26, 0.98	.001	0.62	0.26, 0.97	.001
Sunday	0.01	−0.34, 0.35	.97	0.60	0.24, 0.95	.001
Year (per year after 2003)	−0.03	−0.10, 0.05	.43	−0.03	−0.11, 0.04	.33
Age (per year after 15)	0.15	0.04, 0.25	.008	0.05	−0.06, 0.15	.38
Female sex	0.25	0.08, 0.42	.004	−0.07	−0.27, 0.13	.48
Race						
Caucasian	Reference			Reference		
African American	0.40	0.11, 0.70	.007	−0.04	−0.30, 0.22	.75
Asian	0.28	−0.05, 0.61	.09	0.78	0.02, 1.54	.04
Hispanic	−0.20	−0.47, 0.06	.13	0.01	−0.24, 0.26	.93
Other	0.13	−0.32, 0.58	.57	0.27	−0.26, 0.80	.32
ln (income)*	0.09	−.004, 0.19	.06	0.03	−0.05, 0.11	.43
Activities (per hour)						
Child care activities*	0.17	0.05, 0.28	.005	−0.09	−0.28, 0.10	.36
Educational activities*	0.05	0.01, 0.08	.007	−0.32	−0.37, −0.28	<.001
Social activities*	0.25	0.20, 0.30	<.001	−0.07	−0.13, −0.01	.02
Sports activities*	0.08	0.02, 0.14	.007	−0.14	−0.21, −0.07	<.001
TV watching*	0.15	0.10, 0.20	<.001	−0.05	−0.10, 0.01	.10
Work activities*	0.12	0.07, 0.16	<.001	−0.18	−0.24, −0.13	<.001
Computer use*	0.26	0.16, 0.37	<.001	0.04	−0.07, 0.16	.45

The coefficients represent the fraction of an hour (eg, .50 = 30 minutes) associated with a 1-unit change in the predictor.
*These variables were centered at their means.