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Sociodemographic and behavioral predictors of bed time and wake time among U.S. adolescents aged 15–17 years

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Abstract

Objective—To examine bed times and wake times in US adolescents aged 15–17 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 two 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 1–2 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 however that this is a recent change in bed times and wake times. Although many factors influence bed time, school start time is the strongest determinant of wake times on school days. Increased computer use and earlier school days may be contributing to insufficient sleep among adolescents.

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 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 on average 9 hours of sleep (2,3). Both experimental and observational studies have found deleterious health and behavioral consequences of shorter sleep durations in adolescents and young adults. Adequate sleep appears to be critical for improved school performance and cognitive performance (4,5). Furthermore, one study observed increased risk-taking behavior among adolescents who experienced more sleep problems (6). Studies in young adults have found that sleep loss can also lead to impairments in neurobehavioral performance, mental health, immune function, appetite regulation and glucose metabolism (7–10). Population-based studies have also observed an association between sleep duration and obesity among adolescents (11–13). Finally, sleep loss increased the risk of motor vehicle accidents in young adults (14), and sleep related crashes occur more often among adults under 25 years of age (15). Traffic accidents

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are the number one cause of death among adolescents (16). Thus it is concerning if adolescents are only sleeping 7–7.5 hours per night.

In this study we use 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 two questions about adolescent sleep behavior: (1) Have adolescent bed times and wake times changed in recent years? (2) What factors determine adolescent bed times and wake times?

Methods

Samples

These data come from two different population-based studies in the U.S. 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 non-institutionalized population. One household member aged 15 or older was randomly selected from CPS households to participate in ATUS. Only one time diary was collected from each participant. Time diaries were collected using computer-assisted telephone interviewing. Our analyses are restricted to the adolescents in the sample, respondents aged 15 to 17 years.

The second sample is the Time Use Longitudinal Panel Study, 1975–1981, a national two-wave panel survey (18). The 1975 data only included adults, but in 1981 up to three children from each household were eligible to participate. Each child participant was asked to complete two time diaries: one school day and one non-school day. The time diaries were collected during personal interviews. Our analyses include children aged 15 to 17 years for comparability to 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 each activity began and ended (17,19,20). Unlike a survey question about usual time spent in a particular activity (e.g. “How many hours do you spend watching television?”), time diaries do 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 than time diaries (17,21). Thus, time diaries are believed to be a more accurate method for measuring daily behavior.

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

Time Diary Variables

Bed time—Bed time was the time when the final evening sleep period began during the 24 hour period. Because there may have been more than one sleep episode over the 24 hours, we used the last sleep start time after 6:00 p.m. (but before 6 a.m.) as representative of bed time. If the respondent indicated that he/she was asleep when the time diary began (4:00 a.m. in ATUS or midnight in the 1981 data) that was not considered a bed time because we cannot determine the true beginning of the sleep period.

Wake time—Wake time was 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 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 sleeping for a single night.

School Start time—School start time was the time that the educational activity of taking a class began on the diary day. Only 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 studies: work, child care, education, social entertainment, sports/active leisure; watching television, and computer use.

School day versus non-school day—We identified diaries as a school day if the diary indicated time spent taking a class on that day. If not, it was considered a non-school day.

Additional covariates included age, sex, race (white, black, 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 during 2003). We converted the categorical income data into a single continuous variable by assigning the midpoint of each income category as income, and for the top category we used the pareto estimate of the mean (22). Due to inflation, income was adjusted 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

There were two parts to the analysis: (1) a comparison of mean bed times, wake times and time in bed in 2003–2006 ATUS with the 1981 sample to address our first study question, and (2) an analysis of the predictors of bed times and wake times in the ATUS study only to address the second question.

We created box plots depicting the median, 25th percentile and 75th percentile by day of week for bed times, wake times and time in bed in the 1981 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 two time periods. Separate models were calculated for school days and non-school days. For the 1981 data we also took into account the repeated diaries in some adolescents using the clustered sandwich estimator. Finally, we tested whether the 1981 bed time, wake time, and inferred time in bed differed from the 2003–2006 ATUS data using regression models that included a dummy variable identifying the 1981 study after adjusting for age, race and sex.

The second part of our analyses involved separate linear multiple regression models predicting bed time and wake time using the 2003–2006 ATUS data only. These results indicated which factors predict bed time and wake time. The outcome in each model was clock time on a scale from 0 to 24. The predictors were sociodemographic factors (age centered at 15, sex, centered natural log of household income), the amount of time spent in different activities during the sample day (time spent in education, sports, television, computers, socializing, child-care and employment) and the day of week of the diary (Monday was reference category). All activities were centered at their means. All analyses were performed using Stata 10.0 (Stata Corp). Analyses were restricted to time diaries collected during the months of September through November and January through April because those are the months when school is in session; they are also the months when the 1981 data were collected.

Results

The sample descriptions from the 1981 Time Use Longitudinal Panel Study and by year from ATUS (2003–2006) are presented in Table I. The 1981 sample is much smaller (n=130) than any single year of ATUS. Age and sex (but not race) distribution was similar across all samples.

(1) 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 and ATUS data. None of these means differed significantly between the two studies (p>.05).

(2) 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. Friday and Saturday bed times were significantly later than 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 15 minutes later on average than boys. With a smaller representation, it appeared that African-American adolescents went to bed almost 25 minutes later than white adolescents. Each additional $25,000 of family income was associated with bed time approximately 1 hour later. All of the activity categories were significantly associated with bed time, but computer use and social activities had the strongest effects. Every hour increase in either of these activities delayed bed time by about 15 minutes. Television and working had intermediate effects as they were associated with a bedtime delay of 7–9 minutes for each hour spent on the activity, and hours in school, childcare and sports had minimal effects.

There were fewer significant predictors of wake time than 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. Black and Hispanic adolescents did not differ significantly from whites, but the small sample of Asian adolescents woke up 45 minutes later on average than white adolescents. Of the daily activities, educational activity was the strongest predictor of wake time. Every additional hour of educational activity was associated with waking 19 minutes earlier on average. Every hour of work and every hour of sports advanced wake time by approximately 8–11 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 a highly significant predictor of wake time (beta = .42, 95% CI: .26–.58, p<.001) and none of the activities remained significant (data not shown). Every hour later that school started, wake time was delayed by approximately 25 minutes.

Discussion

Our results indicate that adolescents spend about 8–8.25 hours in bed on school days and 10–11 hours on non-school days. Thus, school day bed times and wake times are not compatible with estimated sleep need of 9 hours, and extension on non-school days may reflect a sleep debt. Bedtimes were only one hour earlier on school days compared with non-school days but wake times on school days were 2 hours earlier. This is may be due to a delay in the circadian timing of sleep onset that is observed in many adolescents (2), which means that many adolescents are unable to go to bed earlier on school days to obtain adequate amounts of sleep. Interestingly, these bed times do not appear 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 examining only school days, school start time was the strongest predictor of wake time; an hour later delay in school start predicted a delay in wake time by 25 minutes.

Since sleeping and television or computer use are mutually exclusive activities, excessive television viewing and/or computer use would necessarily limit time available for sleep, but so would time spent on any other activity. Nonetheless, a number of prior studies have investigated sleep and television or computer use, perhaps because they are perceived as less salubrious than activities such as sports or education, or because they are newer ways to spend time. For elementary schoolchildren in the US and China, greater television viewing was associated with less sleep and more sleep problems (24,25). A longitudinal study observed that greater amounts of television viewing during adolescence predicted sleep problems in young adulthood (26). In our analyses, however, the television effect in the ATUS data was relatively modest, but the effect of computer use on bed times was stronger. A study in Brazil similarly found that increasing computer use among adolescents was associated with reduced sleep duration and reduced subjective sleep quality (27). Studies focused on computer use and/or television do not provide data about whether other activities also effect bed times, or whether the particular impact of computers or television on sleep is different than the effect of similar amounts of time devoted to other activities. Our results provide evidence that computer use had a stronger impact on bed times than most other activities, including television. The exception was socializing which was similar in its impact to computer use.

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

The delayed bed time and wake time observed on non-school days is consistent with the delayed circadian phase observed in many adolescents such that sleep would naturally begin and end later than it would for younger children (2). Therefore, early school start times, which our results indicate were the main predictor of an earlier wake time among adolescents on school days, conflict with adolescent circadian biology. The fact that these adolescents spent 2 hours less time in bed on school days is consistent with one other study among 60 high school seniors that observed sleep duration reduced by an average of 2 hours on school days (28). Another study found that students attending schools with later start times (8:37 AM versus 7:15 AM) obtained almost an hour more sleep (29). Because of evidence of deleterious consequences of early school start times, several schools in Minnesota tried delaying start time by 30 minutes or more, but such a shift is not without controversy (30). Nonetheless, our study does confirm that on school days adolescents are obtaining less sleep then they are thought to need, and the factor with the biggest impact is school start times. If sleep loss is associated with impaired learning and health, then these data point to computer use, social activities and especially school start times as the most obvious intervention points.

Acknowledgments

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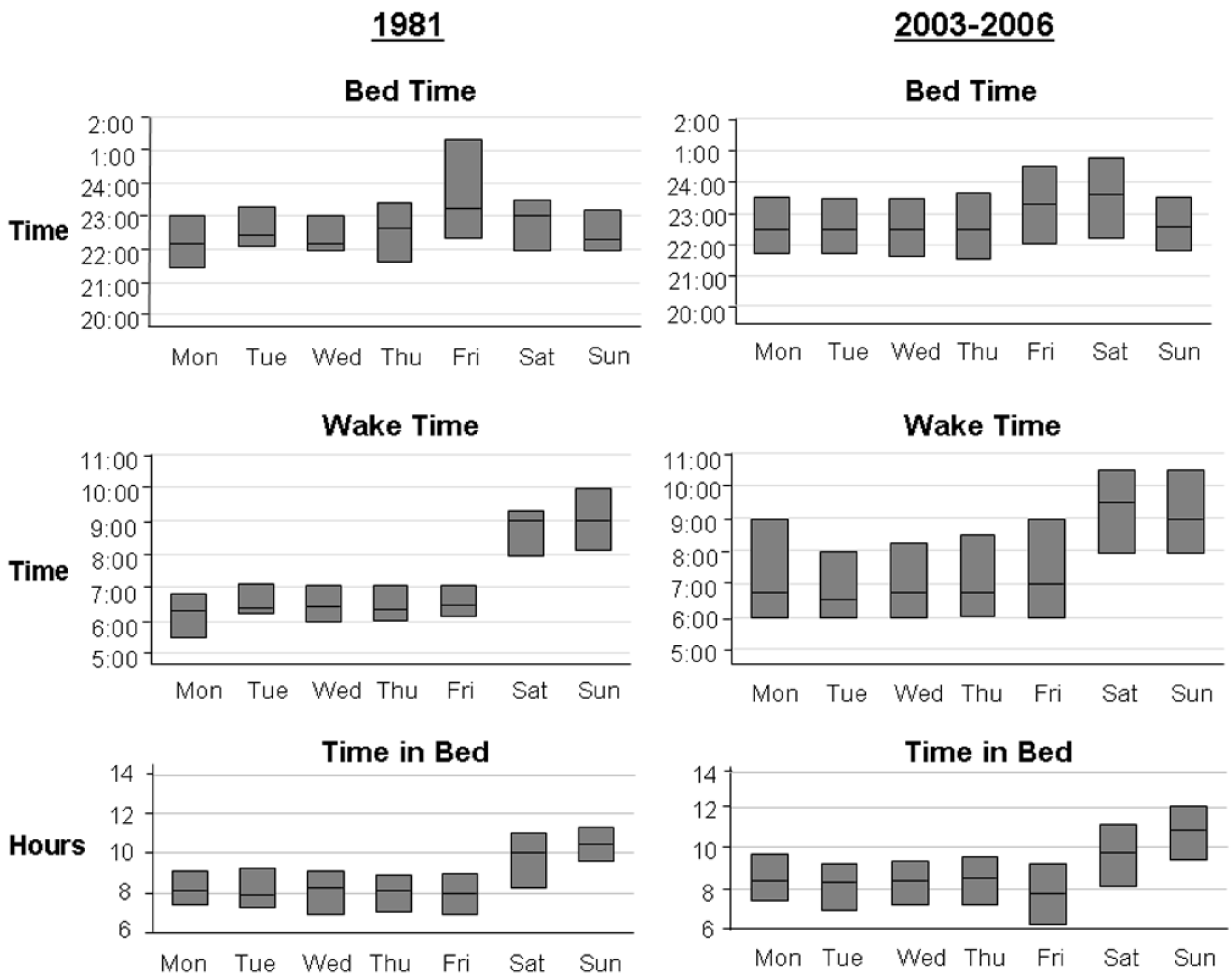

Figure 1.
Figure[H1]. Median and interquartile range of bed times, wake times and total 24-hour sleep times by day of week for the 1981 Time Use Longitudinal Panel Study and the 2003–2006 American Time Use Survey. Top of box represents 75th percentile, bottom of box represents 25th percentile, and line inside box represents 50th percentile (median). Sample weights were used.

Table 1

Descriptive statistics of respondents aged 15–17 years from the 1981 Time Use Longitudinal Panel Study and the 2003 through 2006 American Time Use Surveys.

	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
Proportions					
Female	45%	50%	45%	50%	50%
Race					
White	89%	68%	67%	65%	67%
Black	5%	11%	12%	13%	10%
Asian	0%	3%	3%	4%	4%
Hispanic	5%	14%	14%	15%	17%
Other Race	0%	3%	4%	4%	1%
Household Income ‡					
<$25,000	17%	20%	17%	27%	24%
$25–50,000	33%	25%	27%	26%	28%
$50–75,000	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

‡ Income was adjusted for inflation.

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Table 2

Age-, race- and sex-adjusted means ± standard errors of bed time, wake time and time in bed for respondents aged 15–17 years from the 1981 Time Use Longitudinal Panel Study and the 2003 through 2006 American Time Use Surveys.

	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

Table 3

Multiple regression models predicting bed time (hours) and wake time (hours) among respondents aged 15–17 in the 2003–2006 American Time Use Surveys. The coefficients represent the fraction of an hour (e.g. .50 = 30 minutes) associated with a one-unit change in the predictor.

	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**	**.08, 0.42**	**.004**	−0.07	−0.27, 0.13	.48
RACE						
White	reference			reference		
Black	**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 race	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)						
Childcare activities†	**0.17**	**0.05, 0.28**	**.005**	−0.09	−0.28, 0.10	.36
Educational activities†	**.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

†These variables were centered at their means.