13. Influence of Irregular Sleep Patterns on Waking Behavior

CHRISTINE ACEBO AND MARY A. CARSKADON

Two consistent findings in the literature on adolescent sleep patterns are that time spent sleeping on school nights decreases from childhood through adolescence, and that differences between weekend and school-night sleep schedules are large for many teenagers (Billiard, Alperovitch, Perot, & James, 1987; Strauch & Meier, 1988; Carskadon, 1990; Szymczak, Jasinska, Pawlak, & Swierzykowska, 1993). In general, school-night sleep is restricted because of early school start times, whereas on weekends, bedtimes and rise times are later and total sleep time is longer. In a recent large survey of over 3,000 high school students, Wolfson and Carskadon (1998) found such irregular bedtimes related to self-reported academic difficulty in school, daytime sleepiness, depressed mood, and sleep-wake behavior problems. Lower amounts of self-reported total sleep time were also related to more difficulties with daytime functioning. We suspect that these difficulties in daytime function may result in part from disturbances in both the homeostatic and circadian timing systems regulating sleep-wake behavior.

Evidence from other studies in children and adolescents supports the importance of total sleep time and sleep schedule regularity as predictors of daytime functioning. Several other survey studies have linked total sleep time with grades, daytime fatigue and struggles to

This work was funded by National Institutes of Health (NIH) grant MH45945. We thank Amy Wolfson, Ronald Seifer, Camille Brown, Catherine Darley, François Garand, Liza Kelly, Eric Kravitz, Christopher Monti, Orna Tzischinsky, Beth Yoder, Jennifer Wicks, and Tony Spirito for their assistance with this project. This chapter is based on a paper presented at the UCLA Youth Enhancement Service Conference on Contemporary Perspectives on Adolescent Sleep Patterns, Los Angeles, CA, April 17–20, 1997.

stay awake, and difficulties concentrating in class (Allen, 1992; Epstein, Chillag, & Lavie, 1995). Results from a longitudinal study of teenagers across the 9th to 10th grade transition demonstrated that students decreased sleep by an average of 20 minutes across the transition because of earlier school start times and showed an increase in daytime sleepiness as measured by the Multiple Sleep Latency Test (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998). Results from other survey studies have indicated that adolescents with irregular sleep-wake schedules are more likely to report high levels of daytime sleepiness (Billiard et al., 1987) or to express a need for more sleep (Strauch & Meier, 1988). Acebo and Carskadon (1993) found that bedtime irregularity was related to school functioning as rated by teachers of 5th grade students, with poorer functioning children having more irregularity.

Data from these and other studies provide converging evidence that many adolescents have inadequate sleep patterns both in terms of amount and scheduling of sleep (Wolfson & Carskadon, 1998). Few studies, however, have attempted to assess the unique or relative importance of these two variables for daytime functioning. Manber, Bootzin, Acebo, and Carskadon (1996) reported results from an intervention study in college students that aimed at assessing the effects of increasing sleep time versus increasing schedule regularity. Students in the group given instructions to regularize their sleep patterns showed greater and longer-lasting reductions in self-reported sleepiness and improved self-reported sleep efficiency as compared with students asked only to increase sleep time. The effects were small and based on self-report measures; however, the study provides experimental data supporting an independent contribution of regularity. Furthermore, several laboratory experiments conducted by Taub and colleagues have demonstrated performance and mood deficits in college students when their sleep time was maintained but when the timing was acutely altered (Taub & Berger, 1976).

Data for the present study are taken from a large representative sample of high school students who filled out an anonymous eight-page survey of sleep habits and related behaviors. Previous analyses of this data set have indicated that both low sleep time and irregular bedtimes are related to deficits on measures of daytime functioning (Wolfson & Carskadon, 1998). The purpose of the current analyses was to assess the relative importance of school-night total sleep time, regularity of bedtime schedule, and regularity of sleeping location for predicting a wider

range of measures of daytime functioning using multiple regression analysis.

We hypothesized that these three sleep variables would be important and additive predictors of these outcome measures in adolescents even after statistically controlling for demographic and other variables that are expected to have an impact on daytime functioning.

Methods

Subjects

An eight-page sleep habits survey (view the complete survey form at http://www.sleepforscience.org) was administered in the Fall of 1994 to high school students from four public high schools (one urban, two suburban, and one rural) in three Rhode Island school districts. The survey was completed anonymously by 3,119 students during homeroom classes with a response rate of 88%. The sample (13% grade 9, 32% grade 10, 29% grade 11, and 26% grade 12) was 51.6% female and 48.4% male, ranged in age from 13 to 19 years (mean ages = 15.9 ± 1.12 years), and was 86% Caucasian.

Measures

The survey queried students about their usual sleeping and waking behaviors over the past 2 weeks, accidents and injuries over the past 6 months, health, school performance and attendance, frequency of sleep-related behaviors and complaints, and other issues. For this report, we were interested in assessing relationships between 10 outcome measures and 3 measures of sleep and its scheduling. The sleep measures were reported School-Night Total Sleep Time (to assess quantity of sleep), Weekend Bedtime Delay (to assess regularity of timing of sleep), and Number of Nights Sleeping in the Same Bed (to assess regularity of sleeping location).

School-Night Total Sleep Time was obtained from responses to the survey item: "Figure out how long you usually sleep on a night when you do not have school the next day (such as a weekend night) and fill it in here. (Do not include time you spend awake in bed.)"

Weekend Bedtime Delay was derived by subtracting weekend bedtime from school-night bedtime ("What time to you usually go to bed on school days [weekends]?").

Same Bed was a measure obtained from the question "In the last 2 weeks, have you slept in the same bed: (1) every night, (2) almost every night, (3) a few nights, (4) not at all." Scores ranged from 1 (every night) to 4 (not at all).

To control for some of the myriad factors that are assumed to play a role in daytime functioning, eight variables were selected as control variables. These included: Sex; Age; Race (Caucasian, non-Caucasian); highest level of education expected (Expect); self-assessment of Health; self-report of ADHD and/or individualized education program (ADHD/IEP); use of tobacco, alcohol or drugs (Substance); and use of Caffeine. The questions and response sets for these measures are listed in detail on our lab's web site <http://www.sleepforscience.org>. Ten outcome measures of daytime functioning were derived from survey items. These outcome measures are described briefly here. (Cronbach's alpha was calculated from the current data set for scale items.)

Injury: The number of accidents and injuries over the last 6 months (17 types ranging from cuts to gunshots [question 63]; adapted from Starfield et al., 1995).

Alcohol/Drugs: The number of only those accidents and injuries that occurred while using alcohol or drugs.

Homedays: The number of days home from school during the last two weeks because of sickness or any other reason (question 21).

Grades: Self-reported grades in school (question 14, eight-point scale).

Depress: (Coefficient alpha = .79) Depressive mood scale (Kandel & Davies, 1982).

Sleepy 1: (Coefficient alpha = .70) A sleepiness scale consisting of total responses to items in question 43 asking whether the student had fallen asleep or fought sleep in 10 different situations, such as in conversation, while studying, in class at school, driving, etc. (Carskadon, Seifer, & Acebo, 1991).

Sleepy 2: (Coefficient alpha = .68) A sleepiness scale consisting of total responses to four items (c, d, i, and m in question 45) asking about frequency of feeling tired or falling asleep during the day.

Quality: (Coefficient alpha = .80) A scale consisting of total responses to two items (a and o in question 45) querying the frequency of feeling satisfied about sleep.

Delay: (Coefficient alpha = .70) A scale consisting of total responses to six items (b, f, g, h, j, and k of question 45) asking about the

frequency of behaviors presumed to be related to a phase delay of sleep.

Owl and Lark: (Coefficient alpha = .78) A 10-item morningness/eveningness scale (questions 47–56) based on Smith, Reilly, and Midkiff (1989) that assesses time-of-day preferences for activities.

Data Analysis

Hierarchical multiple regression analyses were performed separately for each outcome variable with the set of control variables, as well as School-Night Total Sleep Time, Weekend Bedtime Delay, and Same Bed as the independent variables. The eight control variables (Sex, Age, Race, Expect, Health, ADHD/IEP, Caffeine, and Substances) were entered on the first step, School-Night Total Sleep Time was entered on the second step, Weekend Bedtime Delay on the third, and Same Bed on the fourth. A second analysis entered Weekend Bedtime Delay on the second step, School-Night Total Sleep Time on the third, and Same Bed on the fourth. Results from this second analysis were remarkably similar to the primary analysis and will not be reported.

The increment in R^2 was determined at each step to assess the unique contribution of the variable (or set of variables) upon entry into the equation. This value thus describes the incremental addition of variance accounted for by the variable or set of variables after accounting for those entered on previous steps.

Partial correlation coefficients were also calculated. A partial correlation can be interpreted as the correlation between the independent variable and the dependent variable when the linear effects of the other independent variables have been removed from both the independent and dependent variable; thus, a partial correlation is the correlation between residualized variables.

The very large sample size in this study virtually ensured that all relationships would be statistically significant. Results will be discussed, therefore, from the perspective of effect sizes (Cohen, 1988). A small effect size is equivalent to a multiple R of .14, squared multiple R of .02, and partial correlation of .10; a medium effect size is equivalent to a multiple R of .36, squared multiple R of .13, and partial correlation of .30; a large effect size is a multiple R of .51, squared multiple R of .26, and partial correlation of .50.

Table 13.1. Means, Standard Deviations, Number of Responses (n), and Minimum and Maximum for Interval Measures

Measures	Mean	Standard Deviation	n	Minimum	Maximum
School-Night Total Sleep Time (min)	438.8	66.9	2,887	150	720
Weekend Bedtime Delay (min)	112.0	72.4	2,878	−420	540
Injury	1.4	1.5	2,707	0	8
Alcohol/Drugs	0.2	.6	1,457	0	8
Homedays	0.9	1.5	2,975	0	10
Grades	5.8	1.4	3,060	1	8
Depress	10.2	2.9	2,905	6	18
Sleepy 1	15.0	3.9	2,820	10	40
Sleepy 2	9.4	3.6	2,901	4	20
Quality	6.6	2.3	2,997	5	30
Delay	11.0	4.5	2,994	5	30
Owl and Lark	26.3	5.1	2,885	10	41

Notes: School-Night Sleep Time and Weekend Bedtime Delay are in minutes. Injury, Alcohol/Drugs, and Homedays are the number of incidents. Grades range from 1 to 8 with 1 indicating Ds and Fs and 8 indicating As. Higher scale values for Depress, Sleepy 1, Sleepy 2, and Delay indicate greater numbers of problems. Higher scale values for Quality indicate higher satisfaction with sleep. Higher values on the Owl and Lark scale indicate greater morningness.

Results

Means and standard deviations for each ordinal variable, along with maxima and minima, are presented in Table 13.1. Overall, students reported that they slept slightly more than 7 hours a night on school nights and delayed bedtime nearly 2 hours on weekends (Wolfson & Carskadon, 1998). They reported on average more than 1 injury during the last 6 months and 0.2 injuries while taking alcohol or drugs. Students averaged nearly 1 day home from school for any reason during the past 2 weeks. Average grades for these students were Bs.

Table 13.2 presents the number of students in each category for categorical measures. The majority of students slept in the same bed every night, although over a third of them did not. Most students said that they expected to finish college, that they were in good or excellent health, and that they did not have ADHD, a learning disability, an individualized education program, or special help for difficulties with school work. Less

Table 13.2. Students Responding in Each Category for Nominal Variables

Variable	Number	Percentage
Same Bed		
Every night	1,963	63.6
Almost every night	947	30.7
A few nights	150	4.9
Not at all	25	0.8
Expect		
May not finish high school	32	1.0
Will finish high school	560	18.2
Will get a college degree	1,156	50.6
Will get a degree beyond college	928	30.2
Health		
Poor	39	1.2
Fair	463	15.1
Good	1,718	55.9
Excellent	856	27.8
ADHD/IEP		
No	2,711	89.0
Yes	336	11.0
Substances		
No use of alcohol, tobacco, or drugs	2,098	69.1
Use 1 of alcohol, tobacco, or drugs	553	18.2
Use 2 of alcohol, tobacco, or drugs	235	7.7
Use 3 of alcohol, tobacco, or drugs	149	4.9
Caffeine		
Never drinks caffeinated beverages	417	13.7
Drinks either caffeinated sodas or coffee/tea	1,612	52.9
Drinks caffeinated sodas and coffee/tea	1,017	33.4

than one-third of students reported using alcohol, tobacco, or drugs, but the majority reported drinking caffeinated beverages.

Table 13.3 presents the multiple R, multiple R^2, and the increment in R^2 upon entry of the variable or set of variables into the equation. The increment in R^2 indicated "small" additive effects for School-Night Total Sleep Time for depressed mood, both sleepiness variables, the quality-of-sleep scale, the delay scale, and the Owl/Lark scale. Thus, *after* the control variables are partialed, School-Night Total Sleep Time accounts for between 2% to 5% of the variance for these measures. Weekend Bedtime Delay and Same Bed showed "small" effect size increments only for the Delay scale. The set of eight control variables accounted for between 4% to 28% of the variance for the dependent variables.

Table 13.3a. Multiple R, R^2, and the Increment in R^2 for Variables upon Entry into a Hierarchical Multiple Regression Analysis

Dependent Variable	R	R^2	R^2 Increment
Injury			
Control Variables	.21	.04	.04*
School-Night TST	.21	.04	.00
Weekend Bedtime Delay	.21	.05	.00
Same Bed	.23	.05	.01
Injury with Alcohol/Drugs			
Control Variables	.36	.13	.13**
School-Night TST	.37	.14	.00
Weekend Bedtime Delay	.37	.14	.00
Same Bed	.38	.15	.01
Homeday			
Control Variables	.29	.09	.09*
School-Night TST	.31	.09	.01
Weekend Bedtime Delay	.31	.10	.00
Same Bed	.35	.12	.02*
Grades			
Control Variables	.53	.28	.28***
School-Night TST	.53	.28	.00
Weekend Bedtime Delay	.54	.29	.01
Same Bed	.55	.30	.00
Depressed Mood			
Control Variables	.43	.18	.18**
School-Night TST	.45	.20	.02*
Weekend Bedtime Delay	.45	.20	.00
Same Bed	.45	.21	.00

Notes: * = small effect size; ** = medium effect size; *** = large effect size.

Table 13.4 presents partial correlation coefficients from the analyses. We see from these results that when the linear effects of the independent variables are removed from each other and from the dependent variable, "small" effect size correlations remain between School-Night Total Sleep Time and six of the dependent variables. Thus, after this adjustment for the control variables, lower School-Night Total Sleep Time was related to more symptoms on the depressed-mood scale, more responses on both sleepiness scales, lower satisfaction with sleep, more behaviors indicating delayed sleep phase, and more eveningness on the Owl/Lark scale.

Weekend Bedtime Delay had small effect size partial correlations with grades, the Delay scale, and the Owl/Lark scale. Thus, after adjustment

Table 13.3b. Multiple R, R^2, and the Increment in R^2 for Variables upon Entry into a Hierarchical Multiple Regression Analysis

Dependent Variable	R	R^2	R^2 Increment
Sleepy 1			
Control Variables	.37	.13	.13**
School-Night TST	.40	.16	.03*
Weekend Bedtime Delay	.40	.16	.03*
Same Bed	.41	.17	.01
Sleepy 2			
Control Variables	.39	.15	.15**
School-Night TST	.42	.18	.00
Weekend Bedtime Delay	.42	.18	.00
Same Bed	.43	.19	.01
Quality			
Control Variables	.28	.08	.08*
School-Night TST	.36	.13	.05*
Weekend Bedtime Delay	.36	.13	.00
Same Bed	.36	.13	.00
Delay			
Control Variables	.41	.17	.17**
School-Night TST	.44	.20	.03*
Weekend Bedtime Delay	.47	.22	.01
Same Bed	.47	.22	.01
Owl/Lark			
Control Variables	.36	.13	.13**
School-Night TST	.42	.18	.05*
Weekend Bedtime Delay	.43	.19	.01
Same Bed	.44	.19	.00

Notes: * = small effect size; ** = medium effect size; *** = large effect size.

for the control variables, larger bedtime delays on weekends were related to lower grades, more behaviors indicating delayed sleep phase, and more eveningness on the Owl/Lark scale.

Small effect size partial correlations between the dependent variables and Same Bed were evident for Injuries with Alcohol/Drugs, Days Home from School, and the first Sleepiness scale. Thus, students who slept in the same bed every night were less likely to have injuries associated with drugs or alcohol, days home from school, and daytime sleepiness.

As expected, many of the control variables were correlated with the dependent variables. Sex was related to Grades, Depressed Mood, and Quality of sleep, with girls on the average showing higher grades,

Table 13.4a. Partial Correlation Coefficients from Multiple Regression Analysis

Dependent Variable	Injury	Injury with Alcohol/ Drugs	Homeday	Grades	Depressed Mood
Multiple R	.23*	.38**	.35*	.55***	.45**
Multiple R^2	.05*	.15**	.12*	.30***	.21**
Partial Correlations					
Sex	−.07	−.05	.06	.13*	.30**
Age	−.09	−.01	.07	.03	.04
Race	.00	.01	.00	.01	.02
Expect	.03	.04	−.13*	.37**	.01
Health	.00	−.01	−.05	.11*	−.18*
ADHD/IEP	.06	.04	.07	−.14*	.09
Substances	.13*	.31**	.10*	−.16*	.11*
Caffeine	.00	−.05	.03	−.03	.03
School-Night TST	−.05	−.06	−.08	−.05	−.16*
Weekend Bedtime Delay	.02	.00	.03	−.11*	.00
Same Bed	.09	.11*	.16*	−.07	.06

Notes: Partial correlation coefficients from multiple regression analysis for each dependent variable, and multiple R and R^2 for the set of all variables. * = small effect size; ** = medium effect size; *** = large effect size.

more symptoms of depressed mood, and less satisfaction with sleep. Partial correlations with Age and Race did not reach small effect size criteria for any measure. Expected level of education was related negatively to Days Home from School and positively to Grades. Students who reported better Health tended to report higher grades, less depressed mood, more satisfaction with sleep, and tended toward morningness on the Owl/Lark scale. Students reporting ADHD or help with school work reported lower grades in school. Substance use was related to all variables except Sleep Quality in expected directions. Partial correlations with Caffeine use did not reach small effect size criteria for any measure. Figures 13.1, 13.2, and 13.3 illustrate additive effects and partial correlations between variables for Days Home from School, Grades at School, and Depressed Mood.

The multiple R values estimating the correlation between the 11 independent variables and each outcome variable indicated medium effect

Table 13.4b. Partial Correlation Coefficients from Multiple Regression Analysis

Dependent Variable	Sleepy 1	Sleepy 2	Quality	Delay Scale	Owl/Lark Scale
Multiple R	.41**	.43**	.36**	.47**	.44**
Multiple R^2	.17**	.19**	.13**	.22**	.19**
Partial Correlations					
Sex	.09	.08	−.14*	−.01	−.01
Age	.01	.04	−.03	−.03	.02
Race	.00	.00	.03	.01	.01
Expect	.01	−.03	−.01	−.05	.15
Health	−.07	−.08	−.13*	−.07	.12*
ADHD/IEP	.07	.02	−.04	.07	−.05
Substances	.23*	.25*	−.04	.26*	−.18*
Caffeine	.07	.08	−.03	.06	−.07
School-Night TST	−.17*	−.17*	.23*	−.20*	.24*
Weekend Bedtime Delay	.00	.03	−.01	.15*	−.10*
Same Bed	.11*	.08	−.05	.09	−.08

Notes: Partial correlation coefficients from multiple regression analysis for each dependent variable, and multiple R and R^2 for the set of all variables. * = small effect size; ** = medium effect size; *** = large effect size.

size multiple correlations for all variables except the Injury and Days Home from School measures, for which small effect size relationships were found. Across the outcome variables, variance accounted for by the 11 independent variables ranged from .05 to .30.

Discussion

Many factors, such as sex, age, race, educational expectations, health, learning disabilities, and substance use contribute to differences in daytime functioning among adolescents. The results of this analysis indicate that even after controlling for several such factors, sleep measures add to prediction. School-Night Total Sleep Time attained small effect size relationships with six of the outcome measures, compared with three each for Weekend Bedtime Regularity and Same Bed. Thus, over this set of outcome measures, School-Night Total Sleep Time might be considered a more important predictor. The regularity variables, however, were related to variables that were not impacted by School-Night Total Sleep Time, that is, Grades, Injuries associated with Alcohol/Drugs, and

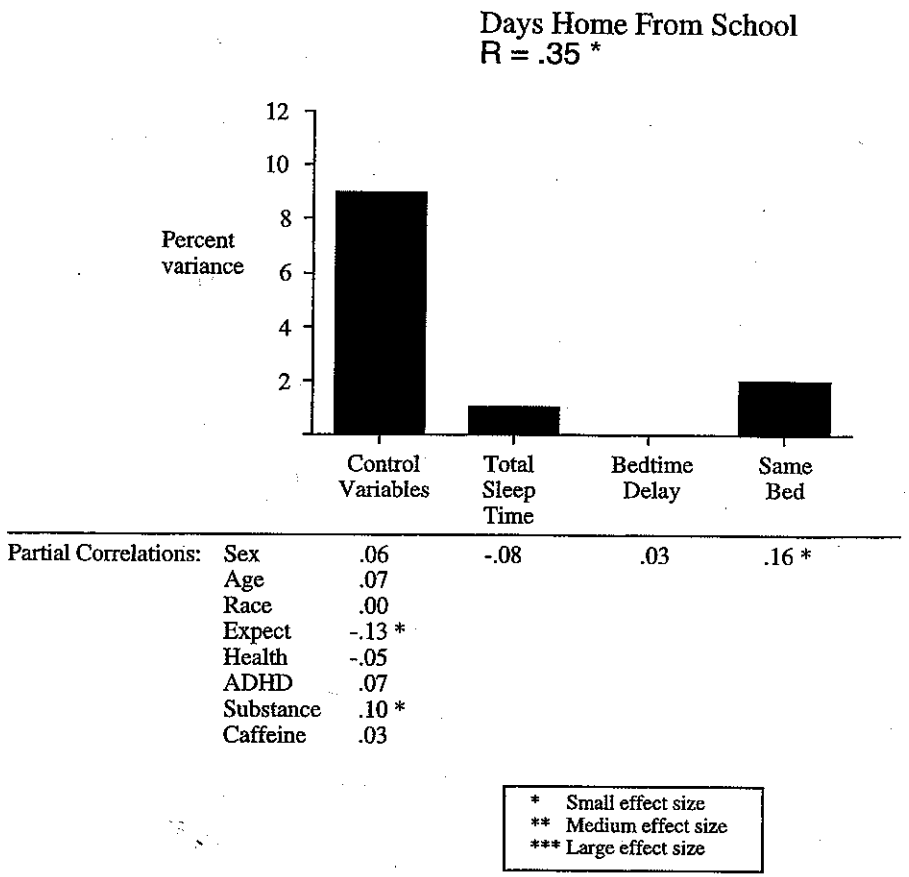
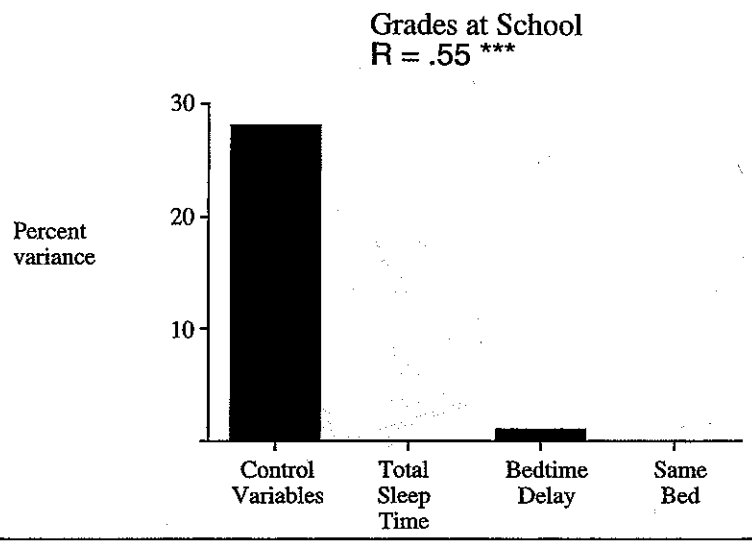


Figure 13.1. Estimated values based on hierarchical multiple regression analysis of Days Home From School with eight control variables entered on step 1, School-Night Total Sleep Time on step 2, Weekend Bedtime Delay on step 3, and Nights in the Same Bed on step 4. The figure illustrates the variance accounted for at each step (the increment in R^2). Partial correlations are tabled for each independent variable.

Days Home from School. All of the relationships were in the expected direction.

The multiple R values for the entire group of independent variables ranged from .23 to .55, indicating at least small effect size relationships for all outcome measures. Thus, the combination of demographic, educational expectation, health, learning disabilities or educational challenge, substance and caffeine use, and sleep measures provide admirable prediction of daytime functioning.

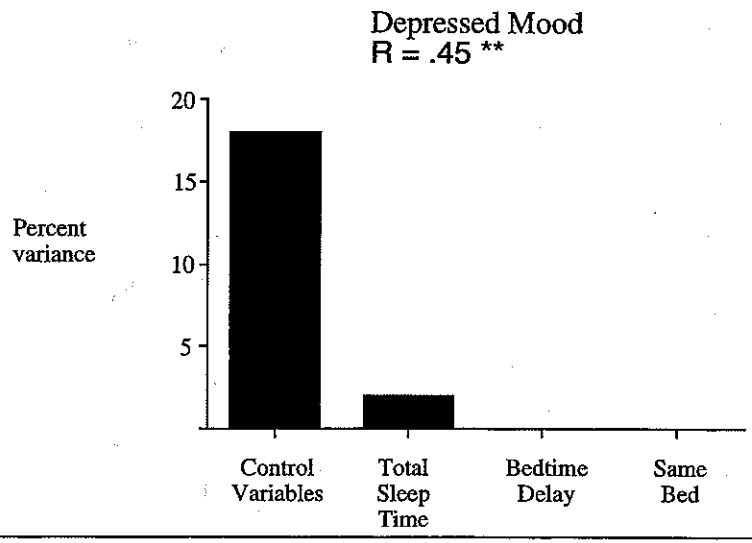


Partial Correlations:					
	Sex	.13 *	.05	-.11 *	-.07
	Age	.03			
	Race	.01			
	Expect	.37 **			
	Health	.11 *			
	ADHD	-.14 *			
	Substance	-.16 *			
	Caffeine	-.03			

* Small effect size
** Medium effect size
*** Large effect size

Figure 13.2. Estimated values based on hierarchical multiple regression analysis of Grades at School with eight control variables entered on step 1, School-Night Total Sleep Time on step 2, Weekend Bedtime Delay on step 3, and Nights in the Same Bed on step 4. The figure illustrates the variance accounted for at each step (the increment in R^2). Partial correlations are tabled for each independent variable.

The results of this study are consistent with other reports in the literature linking inadequate sleep with daytime sleepiness, grades, depressed mood, satisfaction with sleep, and morningness-eveningness in adolescents. In addition, this study adds alcohol- and drug-related injuries and school attendance to the list of measures of daytime functioning associated with less adequate sleep. Inadequate sleep measures were also related to behaviors indicating delayed sleep phase and more eveningness on the Owl/Lark scale. Thus, the teenagers who tend to



Partial Correlations:					
	Sex	.30 **	-.16 *	.00	.06
	Age	.04			
	Race	.02			
	Expect	.01			
	Health	-.18 *			
	ADHD	.09			
	Substance	.11 *			
	Caffeine	.03			

* Small effect size
** Medium effect size
*** Large effect size

Figure 13.3. Estimated values based on hierarchical multiple regression analysis of Depressed Mood with eight control variables entered on step 1, School-Night Total Sleep Time on step 2, Weekend Bedtime Delay on step 3, and Nights in the Same Bed on step 4. The figure illustrates the variance accounted for at each step (the increment in R^2). Partial correlations are tabled for each independent variable.

have less School-Night Total Sleep Time and who delay bedtime more on weekends on average have a preference for scheduling activities later in the day or night and show more behaviors associated with phase delay, such as difficulty getting up in the morning, oversleeping in the morning, difficulty falling asleep at night, and pulling "all-nighters." Decreased School-Night Total Sleep Time for these teenagers is likely a consequence of nonnegotiable early school start times potentiating sleep loss in a phase delayed subgroup.

Finally, although the amount of sleep appears to be a somewhat stronger predictor of daytime dysfunction, irregularity of sleep scheduling and sleep location was also related to outcome measures. We suggest that disturbances in both the homeostatic and circadian systems regulating sleep-wake behavior are indicators of overall system instability and thus may be useful for predicting adolescent dysfunction. Survey data from a variety of studies paint an increasingly coherent picture of the risks to adolescents of inadequate sleep habits, and, although limited by the self-report nature of measures, they provide a strong rationale for longitudinal and laboratory-based studies aimed at assessing the effects of homeostatic and circadian components of the sleep-wake system on daytime functioning.

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