Daily Variation in Adolescents' Sleep, Activities, and Psychological Well Being

Andrew J. Fuligni

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Andrew J. Fuligni

University of California, Los Angeles

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The daily diary method was employed to examine the daily dynamics of adolescent sleep time, activities, and psychological well being among an ethnically diverse sample of over 750 adolescents approximately 14 to 15 years of age. Studying and stressful demands during the day were modestly but consistently associated with less sleep that evening. Receiving less sleep at night, in turn, was modestly but consistently related to higher levels of anxiety, depressive feelings, and fatigue during the following day. In addition, the daily variability in adolescents' sleep time was notable and just as important for the youths' average levels of daily psychological well being as was the average amount of time spent sleeping each night. A small number of ethnic and gender differences emerged in the dynamics of adolescent sleep, activities, and well being. Discussion focuses on the importance of examining daily variability in adolescents' sleep behaviors in order to better understand the implications of sleep for adolescent well being and development.

Daily Variation in Adolescents' Sleep, Activities, and Psychological Well Being

As it does in all periods of the lifespan, sleep serves important rest and restorative functions during adolescence. The teenage years, however, increasingly expose children to activities and demands that can limit their ability to obtain sufficient rest at night. Despite the potential significance of sleep for adolescent development, research on children's sleep behaviors during the teenage years remains somewhat limited. Particularly lacking are studies that closely assess the daily links between sleep, activities, and psychological well being among large, normative samples of adolescents. The present study addresses this need by utilizing the daily diary method in order to examine the daily dynamics of sleep across a two-week period among an ethnically diverse sample of 14 and 15 year old adolescents.

Adolescent Sleep, Activities, and Well Being

Given the decreased need for sleep across the entire life span, it initially was assumed that adolescents needed less sleep than younger children. Studies have indicated, however, that adolescents do not have less of a need for sleep (Carskadon, 1990; Carskadon, Harvey, Duke, Anders, & Dement, 1980). Indeed, adequate sleep appears to be a prerequisite for optimum adolescent functioning and well being. Although the precise biological mechanisms by which sleep impacts health are not clear, the amount and quality of sleep that teenagers receive are associated with psychological and physical well being. Studies have suggested links between less sleep and higher levels of depressed mood, fatigue, and sleepiness (Roberts, Roberts, & Chen, 2001; Wolfson & Carskadon, 1998). Inadequate and poor quality sleep is also associated with diminished cognitive functioning and poor academic performance at school (Wolfson & Carskadon, 1998; Dahl, Holttum, & Trubnik, 1994). The magnitude of these associations tend to

be in the small to moderate range, indicating that sleep behaviors have modest but consistent links with the well being and functioning of teenagers.

Although the implications of sleep for development remain significant during the teenage years, the adolescent period in American society presents challenges to children's ability to obtain adequate rest at night. The transitions to middle and high school force adolescents to start school at earlier times that conflict with a partially biologically-driven circadian phase delay that leads adolescents to prefer later bedtimes (Carskadon, Vieira, & Acebo, 1993; Dahl & Lewin, 2002). Academic demands increase and grading becomes more competitive, resulting in an increased need to study and do homework. The time available for homework after school gets shifted to the evening because of increased socializing with peers and activity involvement in the after-school hours (Larson & Richards, 1991). Adolescents' perceptions of demands in the central domains in their lives – family, peers, and school –increase and potentially compete with one another for the time and attention of teenagers, and stress is known to interfere with individuals' ability to obtain adequate rest (Sadeh & Gruber, 2002). Finally, the increased availability of televisions and computers in the homes and bedrooms of many American adolescents present attractive evening diversions that can cut into time that would otherwise be spent sleeping (Dahl, 2002). Given the number of factors that stand in the way of adolescents' ability to obtain adequate rest, it is not surprising that adolescents, parents, and teachers consistently report that adolescents do not get enough sleep (Wolfson & Carskadon, 1998).

Several laboratory and field studies have explored the dynamics of adolescent sleep in recent years. Only a small number of studies of the natural patterns of sleep among normative populations of adolescents have been conducted, however, and these studies have predominantly employed survey methods (eg., Giannotti & Cortesi, 2002; Roberts et al., 2001; Strauch &

Meier, 1988; Wolfson & Carskadon, 1998). As described above, these studies have made significant contributions by estimating the general patterns and correlates of adolescent sleep behavior. Yet they also possess limitations that can be remedied through the use of alternative methods. Survey studies often ask adolescents to recollect their sleep behaviors from the prior week or two, potentially introducing errors of estimation due to the difficulty inherent in retrospective recall. Correlations between sleep reports and outcomes such as depressed mood may be biased due to the adolescent reporting on both factors within the same survey, and to the possibility that other, unmeasured attributes of the individual adolescent could account for the associations. Finally, it is difficult within a single survey to obtain estimates of the daily variability in adolescents' sleep that go beyond just differences between weekdays and weekends. This final limitation is particularly significant because there has been some suggestion that the variability in children's and adolescents' sleep may be just as important a predictor of adjustment as the average amount of overall sleep (Acebo & Carskadon, 2002; Bates, Viken, Alexander, Beyers, & Stockton, 2002), and methods designed to assess such variability are needed.

A Daily Diary Approach to Adolescent Sleep

The present study employed the daily diary method to examine the daily dynamics of adolescents' sleep time, activity involvement, and psychological well being among an ethnically diverse sample of approximately 750 ninth grade students. Researchers have increasingly employed the daily diary approach to study the rhythm of individuals' lives and to examine how behaviors, experiences, and well being co-occur with one another on a daily basis. In the daily diary approach, study participants are asked to complete diary checklists each day for a short period of time, often ranging from one to two weeks. The checklists ask participants to indicate

whether various events occurred that day, as well as whether the participants engaged in specific behaviors or experienced particular feelings. Asking participants to report experiences every day minimizes the amount of error that occurs in the retrospective reporting of events. This method also allows researchers to estimate whether specific events, behaviors, and feelings co-occur with one another on a daily basis (e.g., do adolescents sleep less on days in which they have a lot of homework or experience stress?). In addition, researchers can estimate the extent to which the co-occurrence of daily-level phenomena varies across individuals and groups (e.g., is the link between study time and sleep time greater for adolescent girls than boys?).

The daily diary approach is particularly useful for understanding the role of sleep in adolescents' lives because it not only enables a close examination at the level of day-to-day experiences, but it also allows researchers to take steps to account for potential confounds inherent in having the same individuals report both their life events and adjustment. If diary reports are obtained on consecutive days, researchers can control for individuals' level of well being on the prior day in order to estimate the association between sleep time and change in well being from the previous day. Although it is impossible to completely eliminate all confounds when using self-reports, the improvements offered by the daily diary method over traditional methods has led the diary method to be used to examine the links between daily experiences and adjustment in a variety of domains, such as the impact of work stress on parent-child interactions (Repetti & Wood, 1997), the link between personality and life stress (Bolger & Zuckerman, 1995), and socioeconomic and gender differences in the reaction to stress (Almeida & Kessler, 1998; Grzywacz, Almeida, Neupert, & Ettner, 2004).

Finally, the availability of daily reports of sleep time allows for a direct estimation of the daily variability in adolescents' sleep time, as was done by Bates, et al. (2002) in a study of

preschool children. Specifically, the extent to which each individuals' daily sleep time deviates from their own average amount of sleep time across the study period can be computed, and the predictive importance of this indicator of variability relative to the average amount of time adolescents sleep can be examined.

Current Study

In the present study, adolescents completed a short diary checklist every night before going to bed for a period of two weeks. Among other events and experiences, the checklists included items regarding the amount of time spent sleeping the prior evening, involvement that day in various activities such as studying and socializing with friends, and feelings that day of psychological well being and fatigue. In the analyses described in this paper, we examined the relevance of six different types of activities and experiences for adolescents' sleep patterns. Studying, socializing with friends, and stressful demands have been suggested in prior survey research to be associated with adolescents' sleep time (Carskadon, 2002; Sadeh & Gruber, 2002). These are common activities and experiences during the adolescent years and can either compete with the time available for sleeping or arouse teenagers to a level that makes it difficult to relax at bedtime. Watching television and playing on the computer have been studied less frequently as correlates of sleep time, but these activities have been suggested to be late-night diversions that can prevent teenagers from getting to sleep at a reasonable hour (Dahl, 2002). Finally, helping the family with chores and other tasks is an activity that has shown variability across different ethnic groups and, at higher levels, could conceivably present an additional demand on adolescents' lives that would cut into the time they have available for sleeping (Fuligni, Yip, & Tseng, 2002).

We also analyzed the implications of sleep time and variability for four different aspects of adolescents' daily mood and psychological well being. Adolescents' daily reports of anxious and depressive feelings were included because of their associations with sleep time in prior survey research, the theoretical links of disrupted sleep with anxiety and depression, and the importance of the adolescent period for the emergence of internalizing disorders. Fatigue was examined in order to assess the obvious links between nightly rest and energy levels during the day, and adolescents' feelings of happiness were analyzed in order to provide an index of positive well being in order to compliment the other indices of negative well being.

The daily diary method allowed us to examine the associations between sleep, activities, and well being at both the individual and the daily level. At the individual level, daily reports were averaged across the fourteen days in order to examine whether adolescents who differ in their mean levels of sleep also differ in their mean levels of activities and well being. Associations observed at the individual level can be interpreted as evidence for the implications of chronic patterns of sleep. For example, do adolescents who typically spend more time studying also typically spend less time sleeping? At the daily level, in contrast, analyses examined whether the experience of sleeping less or more as compared to other days was associated with the daily occurrence of activities or the daily experience of well being within individual adolescents. Associations observed at the daily level, therefore, can be interpreted as evidence for the implications of episodic patterns of sleep. For example, do adolescents feel more depressed on days after they received less sleep? The daily level analyses also allowed us to examine whether there were individual differences in the daily associations between sleep, activities, and well being. For example, are girls more tired on days after they received less sleep than boys? Finally, the daily analyses allowed us to confirm whether the associations found at

the individual level also were found at the daily level. Associations observed at both levels would provide more evidence that sleeping behavior itself was associated with activities and well being. Associations observed at just the individual level, however, could potentially be due to other, unmeasured characteristics of the individual adolescents and not due to sleeping behaviors themselves.

Method

Sample

Ninth grade students were recruited from three public high schools in the Los Angeles metropolitan area whose enrollments reflect the communities from which their students are drawn and vary in terms of ethnic composition, socioeconomic status, and overall level of achievement. The first school is populated by predominately by Latino and Asian American students who come from families with lower-middle to middle-class educational, occupational, and financial backgrounds. This school tends to be in the lower-middle to middle range of the achievement distribution of schools within the state of California. The second school includes students from mainly Latino and European American families who tend to be lower-middle to middle-class in terms of parental education, occupation, and income. Finally, the third school enrolls mostly Asian American and European American students whose families tend to be middle to upper-middle class. The achievement levels of the latter two schools tend to be average and somewhat above-average, respectively. None of the schools were dominated by a single ethnic group; rather, the two most common ethnic groups each comprised approximately 30 - 50% of the total population of students in each school.

In two of the three high schools, the entire population of ninth grade students was invited to participate. In the third high school, approximately half of the ninth graders were invited to

participate because the large size of the school did not make it feasible to recruit all of the students. Across all three schools, 65 percent of those invited to participate actually took part in the study resulting in a total sample of 783 ninth grade students who came from families with a wide rage of ethnic, socioeconomic, and immigrant backgrounds. A total of 761 students provided sufficient information regarding their sleep time and the analyses presented in this paper focus on these students.

The three high schools had similar start times for the first period of classes of either 8:00 AM or 8:15 AM. The schools also offered a few "zero period" classes that began at 7:05 AM or 7:12 AM, but like the typical ninth grade students in these schools, virtually none of the students in our sample attended zero period classes during our study.

Students were from diverse ethnic backgrounds, with the three largest groups being those from Mexican (*n*=228), Chinese (*n*=174), and European backgrounds (*n*=136). The remainder of the students were from other Asian backgrounds (*n*=82), other Latino backgrounds (*n*=34), and other backgrounds such as Middle Eastern and African American (*n*=97). Ethnic background could not be determined for 10 students. Most of the participants from Latino and Asian backgrounds were from immigrant families, being predominantly of the first (youth were born outside of the U.S.) and second (youth were born in the U.S., but at least one parent was foreign-born) generations. In contrast, those from European and African American backgrounds were predominantly of the third generation or greater (youth and both of their parents were born in the U.S.). The sample was relatively evenly split between males (49%) and females (51%).

Students reported how far their parents went in school by responding to a scale that ranged from "Elementary/Junior High School," "Some high school," "Graduated from high school," "Some college," "Graduated from college", to "Law, medical, or graduate school."

Comparisons of the students from the three largest ethnic backgrounds indicated that parents of students with European backgrounds were more likely to have received college degrees than parents of students with Chinese backgrounds, who, in turn, were more likely to have at least attended college than the parents of students with Mexican backgrounds. Students' reports of their parents' jobs were coded into five different categories including "Unskilled," "Semi-skilled," "Skilled," "Semi-professional", "Professional." Ethnic differences in occupational status followed a pattern similar to ethnic differences in education, with parents of students with European backgrounds being employed in higher level occupations than the Chinese parents, who, in turn, worked in higher status occupations than the Mexican parents.

Procedure

Participants were recruited from spring semester classes that all of the ninth grade students were required to take, regardless of their academic ability (e.g., social studies, physical education). Students who returned parent consent forms and provided their own assent to participate completed an initial questionnaire during class time. Consent forms and study materials were available to students and their parents in English, Chinese, and Spanish and 8 participants chose to complete the questionnaires in a language other than English (4 in Chinese and 4 in Spanish).

After completing the initial questionnaire, the students were given a brief demographic questionnaire to complete at home and a 14-day supply of diary checklists for the students to complete at home every night before going to bed over the subsequent two-week period. The diary checklists were only 3 pages long and took about 5-10 minutes to complete. Participants were instructed to complete a diary sheet every night rather than a few at a time in order to maintain the integrity of the data. Participants were called during the two-week period in order

to remind them to complete the diary checklists and to answer any of their questions. In order to monitor completion of the diary checklists, participants were also provided with 14 manila envelopes and an electronic time stamper. The time stamper is a small, hand-held device that imprints the current date and time and is programmed with a security code so that the correct date and time cannot be altered. Participants were instructed to place their completed diary checklist into a sealed envelope each night, and to stamp the seal of the envelope with the time stamper. At the end of the two-period, the students returned the completed materials to the school and received $30 for participating in the study. In addition, the students were told that they would receive two movie passes if inspection of the data indicated that they had completed the diaries correctly and on-time.

The time stamper method of monitoring the completion of the diaries and the cash and movie pass incentives resulted in a high rate of compliance: 97% of the diaries were completed and 86% could be identified as being completed on time, on either the same night or before 12:00 noon the following day. Results from analyses using only those diaries that were definitively completed on time did not differ from analyses using all completed diaries, regardless of when they were completed. Findings reported in this paper, therefore, are based upon analyses using all completed diaries.

Measures

Sleep Time

Each evening for fourteen days, adolescents reported how many hours and minutes they slept the prior night. These daily reports were used as is for the within-person, daily level analyses. For the between-person, individual level analyses, the following estimates were created from these reports: sleep time, school night sleep time, and non-school night sleep time.

These three estimates represent the average number of hours spent sleeping each night (across school nights and non-school nights), each school night (including Sunday but excluding Friday), and each non-school night (including Friday but excluding Sunday), respectively. Two additional indicators were created to represent the degree of variability in the adolescents' sleep time. The first, daily sleep deviation, represents how much adolescents varied across days in their nightly sleep time and was created by taking the mean of the absolute differences between adolescents' average nightly sleep time and each individual night's sleep time. The second, non-school night/ school night difference, represents the difference between the average amount of sleep on school nights and non-school nights. Higher scores on this measure represent more time spent sleeping on non-school nights as compared to school nights.

Daily Activities and Stressful Demands

Each evening for the two week period, adolescents reported the number of hours and minutes that they spent engaging in five different activities: studying outside of school, socializing with friends, watching television, using a computer for fun, and helping the family. Each of the first four activities were single item reports, and the fifth activity was a report of the total amount of time spent in chores such as helping to clean the home, taking care of siblings, and helping parents with official business. These reports were used as is for the within-person daily level analyses, and daily averages were computed for the between-person, individual level analyses.

Adolescents also reported on whether they experienced the following four stressful demands each day: had a lot of work at home, had a lot of work at school, had a lot of demands made by family, and had a lot of demands made by friends. These demands were adapted from similar lists of demands that have been used in other daily diary research of stress and well-being

among adults (e.g., Bolger & Zuckerman, 1995), and represent typical stressful demands experienced by adolescents in the three most important areas of their lives (i.e., family, school, and friends). An index of daily demands was created by summing the number of demands experienced each day (range: 0-4). Because the ninth grade students were generally too young to work, very few of them had part-time jobs (7.5%) and daily reports of "had a lot of work at job" were virtually non-existent and were not used in the index of stressful demands. The index was used as is for the within-person daily level analyses, and a daily average was computed for the between-person, individual level analyses.

Daily Mood

Aspects of adolescents' daily mood were assessed each day for the two week period using subscales of the Profile of Mood States (Lorr & McNair, 1971), a measure that has been used in numerous previous daily diary studies of stress and psychological well being among both adolescents and young adults (Bolger & Zuckerman, 1995; Fuligni et al., 2002). Adolescents used a scale that ranged from 1 ("Not at all") to 5 ("Extremely") to indicate the extent to which they felt anxious feelings (items: on edge, unable to concentrate, uneasy, nervous), depressive feelings (items: sad, hopeless, discouraged), and fatigue (items: exhausted, worn-out, fatigued). In addition, adolescents used the same scale to respond to a set of newly-created items intended to tap happiness (items: joyful, happy, calm). Daily-level alpha coefficients indicated that each multiple-item measure possessed good internal consistency (anxious feelings: .63; depressive feelings: .67; fatigue: .76; happiness: .75). These measures were used as is for the within-person daily level analyses, and daily averages were computed for the between-person, individual level analyses.

Results

Individual-Level Analyses

Traditional analyses were used in order to examine overall trends in adolescents' sleep time and the individual-level associations between adolescents' sleep time, activities and stressful demands, and psychological well being.

Sleep time. On average, adolescents reported spending 7.84 hours (SD=0.98) per night sleeping and their nightly sleep time varied across days by an average of almost one hour (M=0.91; SD=0.53) over the two week period. Adolescents slept three-quarters of an hour more on non-school nights (M=8.41, SD=0.98) than school nights (M=7.66, SD=0.96; t(706)=14.61, p<.001). There was a fair degree of stability in the individual differences in sleep time on different days of the week, with those who slept more on school nights also being likely to sleep more on non-school nights (r=.43, p<.001).

Average sleep time and sleep deviation were related such that adolescents who showed more variability across days tended to sleep less across all days (r=-.20, p<.001) and on school nights specifically (r=-.31, p<.001), but tended to sleep more on non-school nights (r=.18, p<.001).

Boys and girls reported similar amounts of sleep on both school nights and non-school nights, although the daily deviation and the difference between non-school nights and school nights were slightly greater for girls (deviation: $M = 0.95$, $SD = 0.47$; non-school night/school night difference: $M = 0.87$, $SD = 1.44$) than for boys (deviation: $M = 0.87$, $SD = 0.57$; non-school night/school night difference: $M = 0.63$, $SD = 1.29$), ts (715, 696) = 1.99, 2.32, ps<.05. Ethnic differences were examined only among the three groups for which sufficient samples existed (Chinese, Mexican, and European). Mexican students reported significantly more nightly sleep

(M = 8.10, SD = 1.06) than those from Chinese (M = 7.80, SD = 0.86) and European (M = 7.75, SD = 0.96) backgrounds, F (2, 571) = 7.70, p<.001. These ethnic differences in overall sleep were attributable to significant differences in school night sleep (Mexican: M = 7.92, SD = 1.05; Chinese: M = 7.54, SD = 0.87; European: M = 7.58, SD = 0.88), F (2, 570) = 9.90, p<.001. There were no ethnic differences in the amount of time adolescents slept on non-school nights or in the daily deviation and non-school night/school night difference in their sleep time.

Sleep and daily activities and daily demands. Adolescents who spent more time studying, socializing with friends, and playing on the computer spent less time sleeping on a typical night, although the associations were modest (see Table 1). The associations between these activities and sleep time were evident for school night sleep but not for non-school night sleep. The time adolescents spent helping families and watching television was unassociated with overall sleep time, school night sleep time, and non-school night sleep time.

In order to determine the independent associations of the indicators of sleep time with adolescents' daily activities, multiple regressions were conducted in which each daily activity was treated as the dependent variable and average daily sleep time, sleep deviation, and non-school night/school night difference were treated as independent variables. (School night and non-school night sleep times were not included because of their high correlations with each other and average daily sleep time). As shown in Table 2, the time adolescents' spent studying, with friends, and playing on the computer was associated with both the average amount of time they slept and the variability in the amount of time they slept, either across days or between non-school nights and school nights. Specifically, friend and computer time was associated with deviation in sleep time across days, and computer and study time was associated with a greater amount of time spent sleeping on non-school nights as compared to school nights.

Adolescents who reported more stressful demands on a daily basis tended to sleep less on a typical day (r=-.13, p<.001), and this was true for both school night sleep (r=-.11 p<.01) and non-school night sleep (r=-.11 p<.01). Those who reported more stressful demands did not differ from their peers, however, in the variability of their sleep across days or between non-school nights and school nights (rs=.02, -.03, n.s.). Given the lack of association of sleep variability with stressful demands, multiple regressions were not conducted in order examine the independent associations of the different indicators of sleep with stressful demands.

Ethnic differences in adolescents' daily activities and demands were examined in order to determine whether they might account for trend for adolescents from Mexican backgrounds to sleep more than other adolescents. The only ethnic differences in activities and demands in the same direction as the sleep differences were in the tendency for Mexican students to spend less time studying (M = 0.72, SD = 0.59) and playing on the computer (M = 0.40, SD = 0.66) than adolescents with Chinese (studying: M = 1.34, SD = 0.92; computer: M = 1.26, SD = 1.34) and European (studying: M = 1.00, SD = 0.70; computer: M = 0.77, SD = 0.98) backgrounds, Fs (2,573) = 35.43, 36.43, ps<.001. Two-stage hierarchical regression analyses were conducted in order to first estimate the size of the ethnic differences in sleep time and to then examine the extent to which the inclusion of study and computer time reduced the ethnic differences in sleep time. Results indicated that the tendency for Chinese students to spend more time playing on the computer accounted for 44% of their tendency to spend less time sleeping than the Mexican students, and controlling for computer time reduced the ethnic difference to non-significance. In contrast, the ethnic difference in study time only accounted for 29% of the difference in sleep time and the difference between Chinese and Mexican students remained significant after controlling for study time. Study and computer time did little to explain the difference in sleep

time between adolescents with Mexican and European backgrounds, accounting for only 1% and 19% of the difference, which remained significant even after controlling for these activities.

Sleep and daily mood. As shown in Table 3, adolescents who spent less time sleeping on a typical day tended to report more negative and less positive average daily moods. These associations existed for both school night sleep and non-school night sleep, although it was somewhat higher for school night sleep time. Average daily mood also was related to sleep deviation across days, with adolescents who were more variable reporting more negative and less positive moods. The difference between non-school night and school night sleep, however, was unassociated with average daily mood.

In order to determine the independent associations of the different indicators of sleep time with adolescents' average daily mood, multiple regressions were conducted in which average daily sleep time, sleep deviation, and non-school night/school night difference simultaneously predicted adolescents' average daily mood. As shown in Table 4, the daily variability in adolescents' sleep time was consistently related to average mood above and beyond the average amount of time adolescents spent sleeping each night, often times emerging either as strong as or stronger than average sleep time as a predictor. The only exception to this trend was for feelings of happiness. As compared to adolescents with the same amount of sleep, those who are more variable in the amount of sleep they receive tended to report more anxiety, depression, and fatigue. Non-school night/school night difference again generally was not associated with adolescents' average daily mood, except where a tendency to sleep more on non-school nights than school nights was associated with somewhat lower depressive feelings on average.

Daily-Level Analyses

Daily-level associations between adolescents' sleep time, activities, stressful demands, and mood were estimated in order to determine whether they were linked to one another within individual adolescents. These analyses addressed three questions that cannot be answered with the traditional individual-level analyses described above: (1) do adolescents sleep less on nights in which they spend more time in different activities and experience more stressful demands the prior day? (2) do adolescents feel more anxious, depressed, fatigued, and less happy on days in which they have less sleep the prior night?; and (3) are there individual differences in these daily level associations between sleep, activities, demands, and mood? These questions refer to the dynamics of episodic variations adolescent sleep within individual adolescents, whereas the individual-level analyses presented above focus on the dynamics of average patterns of adolescent sleep between individual adolescents. The daily-level analyses were conducted using Hierarchical Linear Modeling (HLM; Bryk & Raudenbusch, 1992), which was designed to analyze nested data of the type that were collected for this study (i.e., daily level data nested within individuals).

Sleep and daily activities and daily demands. HLM models were estimated in which the amount of sleep time on a typical evening was predicted by the amount of time spent in different activities and the number of daily demands experienced by the adolescent that day. Separate HLM models were estimated for each predictor and the statistical model that was estimated was as follows:

$$Sleep\ Time_{ij} = b_{0j} + b_{1j}\,(Activity\ or\ Demands) + b_{2j}\,(School\ Night) + \quad [1]$$

$$b_{3j}\,(Week\ of\ Study) + e_{ij}.$$

Sleep time on a particular evening (i) for a particular adolescent (j) was modeled as a function of the average sleep time of the individual across nights ($\underline{b}_{0j}$) and the time adolescents spent in an activity or the number of demands experienced ($\underline{b}_{1j}$). In addition, whether the evening fell on a school night (Sunday through Thursday) or non-school night (Friday and Saturday) ($\underline{b}_{2j}$) and the week of the study (first or second week) ($\underline{b}_{3j}$) were included as typical controls in daily diary analyses.

As shown in Table 5, adolescents slept less at night after days in which they spent more time studying outside of school and perceived more demands from family, school, and friends. Adolescents' sleep time was not effected, however, by the amount of time they spent on the computer, socializing with friends, or helping family during the day. The time spent watching television was actually associated with more time spent sleeping at night, likely due to the fact that adolescents studied less on days in which they watched more television, b=-.09, p<.001.

Estimates of the degree of individual variability in the daily level associations between sleep, activities, and demands are also provided in Table 5. Significant individual variability existed in the impact of daily studying, socializing with friends, and playing on the computer on the amount of sleep adolescents received the following evening. In contrast, the individual variability in the associations of daily demands, television watching, and family assistance with sleep time was non-significant.

Additional HLM models were analyzed in order to examine whether the significant variability in the daily level associations of studying, socializing with friends, and playing on the computer with sleep time was predicted by adolescents' gender and ethnicity. As before, the analyses focused on the three largest ethnic groups in the sample (Mexican, Chinese, European).

The models included the same daily level equation described in Equation 1 above, this time with the inclusion of the following individual level equations:

$$b_{0j}\,(Average\ Daily\ Sleep\ Time) = c_{00} + c_{01}\,(Gender) + c_{02}\,(Chinese) + c_{03}\,(Mexican) + u_{0j} \quad [2]$$

$$b_{1j}\,(Daily\ Association\ of\ Activities\ with\ Sleep\ Time) = c_{10} + c_{11}\,(Gender) + c_{12}\,(Chinese) + c_{13}\,(Mexican) + u_{1j} \quad [3]$$

Gender was coded as males = 0 and females = 1 and Chinese and Mexican were dummy coded as 0=not Chinese or not Mexican, and 1=Chinese or Mexican, respectively. The ethnicity coding resulted in adolescents with European backgrounds being the baseline group.

Results indicated that adolescents' gender and ethnicity did not significantly predict the variability in the daily level associations of studying, socializing with friends, and playing on the computer with sleep time (*b*s = -.06 to .05, n.s.).

Sleep and daily mood. HLM models were estimated in which the adolescents' daily levels of anxious feelings, depressive feelings, fatigue, and happiness were each predicted by the amount of time adolescents slept during the prior evening. The statistical model that was estimated for each mood index was as follows:

$$Daily\ Mood_{ij} = b_{0j} + b_{1j}\,(Prior\ Evening's\ Sleep\ Time) + b_{2j}\,(Prior\ Day's\ Mood) + b_{3j}\,(School\ Day) + b_{4j}\,(Week\ of\ Study) + e_{ij}. \quad [4]$$

Mood on a particular day (i) for a particular adolescent (j) was modeled as a function of the average mood of the individual across days ($\underline{b}_{0j}$), the time adolescents slept the prior evening ($\underline{b}_{1j}$), and the adolescents' mood on the prior day ($\underline{b}_{2j}$) as a control. In addition, whether the day was a school day (Monday through Friday) or a non-school day (Saturday and Sunday) ($\underline{b}_{3j}$) and the week of the study ($\underline{b}_{4j}$) were included as typical controls in daily diary analyses.

As shown in Table 6, adolescents felt less anxiety and fatigue on days in which they received more sleep during the night, even after controlling for levels of anxiety and fatigue on the prior day. Adolescents also reported marginally lower levels of depressive feelings after spending more time sleeping. Prior nights' sleep was not related, however, to adolescents' subsequent feelings of happiness.

Estimates of the degree of individual variability in the daily level associations between sleep and mood are provided in Table 6. Significant variability existed only in the impact of sleep time on adolescents' fatigue the following day. In contrast, the variability in the associations of sleep time with subsequent anxiety, depressive feelings, and happiness was non-significant.

An additional HLM model was analyzed in order to examine whether the significant variability in the daily level associations of sleep time with fatigue was predicted by adolescents' gender and ethnicity. The models included the same daily level equation described in Equation 4 above, this time with the inclusion of the following individual level equations:

$$b_{0j}\,(Average\ Daily\ Fatigue) = c_{00} + c_{01}\,(Gender) + c_{02}\,(Chinese) + c_{03}\,(Mexican) + u_{0j} \quad [5]$$

$$b_{1j}\,(Daily\ Association\ of\ Sleep\ Time\ with\ Fatigue) = c_{10} + c_{11}\,(Gender) + c_{12}\,(Chinese) + c_{13}\,(Mexican) + u_{1j} \quad [6]$$

Gender was coded as males = 0 and females = 1 and Chinese and Mexican were dummy coded as 0=not Chinese or not Mexican, and 1=Chinese or Mexican, respectively. The ethnicity coding resulted in adolescents with European backgrounds being the baseline group.

Results indicated significant effects of both gender (b=-.03, p<.05) and Mexican ethnicity (b=.04, p<.05) on the daily level association between sleep time and fatigue. Specifically, the effect of sleep time on fatigue was moderately stronger for girls (b=-.08) than for boys (b=-.05),

and the effect was virtually non-existent for adolescents from Mexican backgrounds (b=-.01) as compared to those from European (b=-.05) and Chinese (b=-.05) backgrounds. Nevertheless, there was still a significant amount of variability in the daily association between sleep time and fatigue even after controlling for gender and ethnicity (SD=0.08, $?^2(534)=728.28$, p<.001).

Discussion

The daily assessments of adolescents' sleep that were obtained in this study suggest several insights to be added to our growing understanding about the significance of sleep in adolescents' lives. First, adolescents' sleep time is highly variable across individual days in addition to the previously known difference in sleep time between weekdays and weekends. Second, the variability in adolescents' sleep time is just as important as the average amount of sleep in explaining individual differences in daily psychological well being. Third, studying and stressful demands appear are among the most important factors that can reduce the amount of sleep that adolescents' receive at night. Fourth, daily feelings of anxiety, depression, and fatigue are the most consistent psychological outcomes of obtaining less sleep at night. Finally, a degree of individual variability exists in some of the dynamics of daily sleep, activities, and psychological well being among adolescents. Variability in both the daily patterns and the implications of sleep should be a key focus in future research on the role of sleeping behaviors in adolescent development.

Although the fourteen and fifteen year old adolescents in this study did average approximately 8 hours of sleep per night, which is similar to what has been obtained in other studies (Wolfson & Carskadon, 1998), the amount of daily variability in their sleep time was striking. Adolescents' nightly sleep time varied by an average of almost one hour across fourteen days, a degree of variability that was greater than the forty-five minute difference

between school nights and non-school nights. These results suggest that school night (i.e., weekday) variability is greater than the previously noted difference between weekdays and weekends, and may be uniquely significant for adolescents' daily lives and psychological well being. Indeed, analyses indicated that at the individual level, the variability in adolescents' sleep time was just as important a predictor of average daily psychological well being as the average amount of sleep adolescents' received. Daily variability also was more important for well being than the difference in sleep time between school nights and non-school nights. Given that the participants in this study began school at similar times in the morning, the daily variability in their sleeping time likely was attributable to variations in their daily lives after school hours and in the evening.

Spending more time studying and perceiving more stressful demands from family, peers, and school each day were consistent, albeit modest predictors of receiving less sleep at night. The fact that these associations were observed at both the individual and daily levels suggests that these two experiences in adolescents' lives have both chronic and episodic effects on the students' opportunities to obtain adequate rest at night. The importance of studying and stress in contrast to the other activities examined in this study may lie in their being less controllable and more anxiety-provoking than the other daily activities examined in this study. Although all adolescents do not spend the same amount of time working on the same amount of homework, the length and difficulty level of the homework assigned by teachers do influence amount of study time needed each night. Studying late into the night also likely agitates students enough during the evening to make it difficult for them to fall asleep. Likewise, the perception of stressful demands from the three most important domains in adolescents' lives – family, peers, and school – can create a degree of arousal that makes it difficult for adolescents to sleep.

Similar to the results obtained in other studies of adults and adolescents, therefore, demanding and stressful activities during the day can interfere with teenagers' ability to obtain adequate rest each night and can result in chronically lower amounts of sleep over time (Sadeh & Gruber, 2002).

In contrast to studying and stressful demands, time spent socializing with friends and playing on the computer were associated with less sleep at the individual level but not the daily level. It may be that friend and computer time lead to chronically less sleep on average as opposed to influencing sleep variability on a daily basis. Yet it also may be that the individual-level associations are due to other underlying differences between adolescents that were not measured in this study, such as an extroverted or social orientation that leads to more socializing and perhaps more emailing with friends in the evening. Whatever may account for the individual-level correlations, the lack of daily level associations suggests that the acts of socializing with friends and playing on the computer do not directly result in less sleep at night among adolescents of this age group.

In terms of daily well being, receiving less sleep at night was associated with modestly higher levels of anxious feelings, depressive feelings, and fatigue among adolescents at both the individual and daily levels. These associations perhaps are not surprising given the prior evidence regarding the role of sleep in anxious feelings and affective disorders, as well as the obvious link between inadequate rest and a sense of tiredness and fatigue (Roberts et al., 2001; Wolfson & Carskadon, 1998). It is important to note, however, that these links were observed at the daily level even after controlling for adolescents' feelings on the prior day. These conservative tests should provide more confidence, therefore, in the association between sleep and these indicators of daily psychological and physical well being. Sleep time was associated

with happy feelings at the individual level. Together with the links between sleep time and anxious feelings, depressive feelings, and fatigue at the individual level, this finding suggests the existence of a general "cloud" of negative daily affect that is associated with chronic patterns of inadequate sleep among adolescents, as has been suggested by Carskadon (2002).

Despite the general similarity in the dynamics of sleep across the diverse sample of adolescents, a small number of ethnic and gender differences did emerge. Students from Mexican backgrounds averaged approximately twenty minutes more sleep than did those from Chinese and European backgrounds. In terms of the activities measured in this study, the greater amount of time the Chinese students spent playing on the computer was the best explanation for their sleeping less than their Mexican counterparts, who came from homes with lower socioeconomic backgrounds that presumably were less likely to have computers available to the adolescents (Becker, 2000). Neither computer time nor study time could explain the sleeping difference between those with Mexican and European backgrounds, however, suggesting that there may be other activities or aspects the youths' daily lives that might play a role. Although girls and boys averaged similar amounts of sleep, girls were more variable across the days. It is unclear from the data presented in this paper why this might be the case, and there may be additional activities – such as talking on the phone or emailing with friends – that could explain such a gender difference in the daily variation of sleep time. Finally, these ethnic and gender variations in average sleep time and variability potentially could explain the ethnic and gender differences in the daily implications of sleep for fatigue. The greater amount of overall sleep received by Mexican adolescents could explain why they appeared to be unfatigued by receiving less sleep at night. The tendency for girls to be more fatigued by getting less sleep during the night could be due to the fact that they were more variable in their sleep time than boys, resulting

in an already chronically fatigued state that could be exacerbated each evening the girls did not receive enough rest.

Nevertheless, even after controlling for ethnic background and gender, significant individual variability existed in the effect of sleep on fatigue on a daily level. The same was true for the effects of time spent studying, socializing with friends, and playing on the computer on the amount of sleep received each night. This variability in the daily dynamics of sleep, activities, and well being represent an important area of focus in future research. Why is the daily sleep of some adolescents more or less implicated in their daily lives and well being? In order to answer this important question, the daily diary method employed in this study needs to include additional measures of sleep quality that have been used in other survey studies. For example, by adapting measures used in prior survey research (e.g., Acebo & Carskadon, 2002), students could be asked every day about whether the sleep was satisfying, whether it was disrupted, and the number of times they awoke during the night. Future research also should consider whether there may be temperament or constitutional factors that could produce varying levels of reactivity to nightly sleep among different adolescents.

In addition to better assessing sleep quality and individual temperament, future studies examining the natural daily variation in adolescents' sleep behavior could employ more precise measures of actual sleep time than were obtained in this study. Adapting measures that have been used in some survey studies (e.g., Wolfson & Carskadon, 1998), students could report their actual sleep and wake times instead of simply reporting the amount of time they spent sleeping the prior night. Such a method could conceivably provide more precise estimates of sleep time, and would help to determine whether truncated sleep was due to a later bed time or an earlier wake time. Although the daily changes in sleep time observed in the present study were likely

due more to variability in bed time than wake time because of the similar school start time across the days in the study, assessing sleep schedules would provide more definitive information on what accounts for the daily variation in adolescents' sleep behavior. An additional technique to obtain precise estimates of both sleep time and sleep quality has recently been employed by Axleson, et al. (2003), who asked adolescents to wear wrist actigraphs that detect body movement throughout the day in order to determine exactly when sleep begins and ends, as well as how restless the sleep was during the night.

Finally, it is essential to examine how the daily dynamics of sleep, activities, and well being change across the high school years. Given that adolescents' average sleep time declines by as much as forty-five minutes across the high school years without any change in the apparent need for sleep (Wolfson & Carskadon, 1998), it would be interesting to examine whether developmental changes also exist in the daily variability in sleep behaviors and in the daily implications of sleep for psychological well being. Adolescents' increased involvement in part-time employment, the greater academic demands of the later years of high school, and the greater involvement and stress with peer relationships suggest that the crunch upon adolescents' ability to obtain adequate rest only increases as they progress through the high school years (Wolfson & Carskadon, 1998). It would be important, therefore, to continue examining the daily variability and dynamics of sleep as adolescents progress through a period that is typically associated with the onset of depression and other affective disorders (Roberts et al., 2001).

In conclusion, sleep time is modestly but consistently associated with studying, stressful demands, anxiety, depressive feelings, and fatigue among ethnically-diverse fourteen and fifteen year old adolescents. Daily variability appears to be just as important as average sleep time for adolescents' psychological well being, and the daily diary technique employed in this study is

one effective way to assess such variability. If supplemented with additional measures and recent technological advances to examine sleep behavior and quality, direct examinations of daily variability in sleep dynamics can continue to further our understanding of the role of sleep in adolescent well being and development.

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Table 1

Correlations of sleep indicators with adolescents' daily activities

	Studying	Friends	Television	Computer	Family
	r	*r*	*r*	*r*	*r*
Daily sleep	-.11 **	-.12 ***	.07	-.14 ***	.02
School night sleep	-.19 ***	-.13 ***	.05	-.17 ***	.00
Non-school night sleep	.04	-.06	.06	-.02	.04
Sleep deviation	.05	.10 **	-.04	.10 **	.05
Non-school night/ School night difference	.19 ***	.02	.04	.10 **	.05

Note. – All variables represent the average daily amount of time in each activity. Sleep deviation represents the mean absolute amount of daily deviation in adolescents' sleep time from their own mean, and non-school night/school night difference represents the difference between adolescents' sleep time on non-school nights and school nights with higher scores representing more sleep on non-school nights. *N*s = 707 – 761. * $p<.05$, ** $p<.01$, *** $p<.001$

Table 2

Multiple regressions of adolescents' daily activities using sleep indicators

	Studying	Friends	Television	Computer	Family
	ß	*ß*	*ß*	*ß*	*ß*
Daily sleep	-.18 **	-.10 ***	.05	-.15 ***	.01
Sleep deviation	-.05	.11 **	-.04	.09 *	.04
Non-school night/ school night difference	.24 ***	-.01	.05	.09 *	.04
R^2	.07 ***	.02 ***	.00	.04 ***	.00

Note. – All variables represent the average daily amount of time in each activity. Sleep deviation represents the average amount of daily deviation in adolescents' sleep time from their own mean, and non-school night/school night difference represents the difference between adolescents' sleep time on non-school nights and school nights with higher scores representing more sleep on non-school nights. *N*s = 707. * $p<.05$, ** $p<.01$, *** $p<.001$

Table 3

Correlations of sleep indicators with adolescents' daily mood

	Anxiety	Depression	Fatigue	Happiness
	r	*r*	*r*	*r*
Daily sleep	-.21 ***	-.17 ***	-.21 ***	.13 ***
School night sleep	-.23 ***	-.16 ***	-.20 ***	.15 **
Non-School night sleep	-.11 **	-.13 ***	-.10 **	.06
Sleep deviation	.23 ***	.16 **	.20 ***	-.09 *
Non-school night/ school night difference	.04	-.03	.07	-.04

Note. – Sleep deviation represents the average amount of daily deviation in adolescents' sleep time from their own mean, and non-school night/school night difference represents the difference between adolescents' sleep time on non-school nights and school nights with higher scores representing more sleep on non-school nights. *N*s = 707 – 761. * $p<.05$, ** $p<.01$, *** $p<.001$

Table 4

Multiple regressions of adolescents' daily mood using sleep indicators

	Anxiety ß	Depression ß	Fatigue ß	Happiness ß
Daily sleep	-.18 ***	-.12 **	-.20 ***	.12 **
Sleep deviation	.24 ***	.20 ***	.19 ***	-.08
Non-school night/ school night difference	-.02	-.09 *	.02	-.03
R^2	.10 ***	.06 ***	.09 ***	.03 ***

Note. – Sleep deviation represents the average amount of daily deviation in adolescents' sleep time from their own mean, and non-school night/school night difference represents the difference between adolescents' sleep time on non-school nights and school nights with higher scores representing more sleep on non-school nights. *N*s = 706 – 707. * $p<.05$, ** $p<.01$, *** $p<.001$

Table 5

Hierarchical linear models predicting nightly sleep time by time spent in activities and stressful demands the same day

	Studying	Friends	Television	Computer	Family	Demands
	b (SE)	*b (SE)*	*b (SE)*	*b (SE)*	*b (SE)*	*b (SE)*
Intercept	8.03 ***	7.95 ***	7.90 ***	7.96 ***	7.96 ***	7.99 ***
Activity/demands	-.09 (.01) ***	.00 (.01)	.03 (.01) ***	-.01 (.02)	-.03 (.02)	-.06 (.02) **
School night	-.26 (.02) ***	-.30 (.02) ***	-.30 (.02) ***	-.31 (.02) ***	-.31 (.02) ***	-.30 (.02) ***
Week of study	-.04 (.01) **	-.03 (.02) **	-.03 (.01) **	-.03 (.01) **	-.03 (.01) **	-.04 (.01) **
Standard deviation of activity/demand estimate	.21 ***	.08 ***	.10	.17 ***	.11	.15

Note. – Nightly sleep time was the dependent variable in all analyses. "Activity/demands" represents the effects of the activities or demands listed at the top of the column. School night was coded non-school night=-1 and school night=1 and week of study was coded first week=-1, second week=1. "Standard deviation of activity/demand estimate" is an estimate of the degree of individual variability in the effects of activity/demands on sleep time. * $p<.05$, ** $p<.01$, *** $p<.001$

Table 6

Hierarchical linear models predicting daily mood by time spent sleeping during the prior evening, after controlling for mood on the prior day

	Anxiety	Depression	Fatigue	Happiness
	b (SE)	*b (SE)*	*b (SE)*	*b (SE)*
Intercept	0.61 ***	0.40 ***	1.12 ***	1.79 ***
Sleep time	-.02 (.00) ***	-.01 (.00) +	-.05 (.01) ***	.01 (.01)
Prior day's mood	.19 (.01) ***	.21 (.02) ***	.24 (.01) ***	.20 (.01) ***
School day	.06 (.01) ***	.03 (.01) ***	.08 (.01) ***	-.06 (.01) ***
Week of study	-.04 (.01) ***	-.02 (.01) **	-.05 (.01) ***	.00 (.01)
Standard deviation of Sleep time estimate	.03	.03	.07 ***	.03

Note. – School day was coded non-school day=-1 and school day=1, and week of study was coded first week=-1, second week=1. "Standard deviation of sleep time estimate" is an estimate of the degree of individual variability in the effects of daily sleep time on daily mood. + $p<.10$, * $p<.05$, ** $p<.01$, *** $p<.001$