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Temporal Relationships Between Napping and Nocturnal Sleep in Healthy Adolescents

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Abstract

Many adolescents do not achieve the recommended 9 hr of sleep per night and report daytime napping, perhaps because it makes up for short nocturnal sleep. This article tests temporal relationships between daytime naps and nighttime sleep as measured by actigraphy and diary among 236 healthy high school students during one school week. Mixed model analyses adjusted for age, race, and gender demonstrated that shorter actigraphy-assessed nocturnal sleep duration predicted longer napping (measured by actigraphy and diary) the next day. Napping (by actigraphy and diary) predicted shorter nocturnal sleep duration and worse sleep efficiency that night measured by actigraphy. Diary-reported napping also predicted poorer self-reported sleep quality that night. Frequent napping may interfere with nocturnal sleep during adolescence.

Sleep in adolescence has been called a “perfect storm,” a term that illustrates the biological, academic, social, and behavioral factors that, in combination, lead to insufficient sleep during this developmental period (Carskadon, 2011). Experimental data indicates that 9 hr of sleep is optimal for adolescents (Carskadon et al., 1980), as instantiated in recent National Sleep Foundation and American Academy of Sleep Medicine guidelines (Hirshkowitz et al., 2015). Unfortunately, mounting evidence suggests many adolescents obtain *insufficient* sleep, generally defined as fewer than 8 hr per night (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998; Gau & Soong, 1995; Iglowstein, Jenni, Molinari, & Largo, 2003; McKnight-Eily et al., 2011; Mercer, Merritt, & Cowell, 1998; National Sleep Foundation, 2006; Roberts, Roberts, & Duong, 2009; Roberts, Roberts, & Xing, 2011; Wolfson & Carskadon, 1998). A biological change during puberty involves a circadian delay, such that adolescents prefer later bedtimes and wake times (Carskadon, Viera, &

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SUPPLEMENTAL MATERIAL

Supplemental data for this article can be accessed on the publisher’s website.

Acebo, 1993; Crowley, Acebo, & Carskadon, 2007), even when wake times are constrained by early school start times. More time is spent in social and extracurricular activities and utilizing technology before bed (Calamaro, Mason, & Ratcliffe, 2009), leading adolescents to prefer wake activities over sleep. Thus, a combination of factors contributes to insufficient nocturnal sleep during adolescence.

What do adolescents do about their deficits in nocturnal sleep? One behavior that adolescents may engage in to make up for lost nocturnal sleep is daytime napping. According to the National Sleep Foundation 2011 Sleep in America Poll, approximately 53% of a random sample of 171 teens, 13- to 18-year-olds, reported taking at least one nap on weekdays, and 33% reported napping at least once on weekends or nonschool days; these naps lasted on average 43 min on weekdays or school days and 46 min on weekends (National Sleep Foundation, 2011). In another sample of 100 healthy American adolescents, 37% reported napping on weekdays and 42% reported napping on weekends (Calamaro et al., 2009). Extending beyond survey data reports of napping, in a sample of 92 Brazilian high school students, average actigraphy-assessed minutes napped on school days were associated with shorter sleep duration averaged across the same nights, after adjustment for age, sex, race, work status, smoking and drinking habits, and physical activity (Fischer, Nagai, & Teixeira, 2008). No descriptive data on napping were provided. Taken together, these findings suggest that adolescents who get less nocturnal sleep may also sleep more during the day. However, the temporal sequence is unclear. Does shorter nocturnal sleep duration lead to adolescents' subsequent napping, or does napping during the day result in less nocturnal sleep, or is there no temporal relationship?

To our knowledge, only two studies have examined the temporal relationships between napping and nocturnal sleep, albeit in samples of middle-aged and elderly adults. In a sample of 224 men and women between the ages of 45 and 78, actigraphy-assessed nocturnal sleep variables and daily diary-reported daytime napping were measured across 10 days (Owens et al., 2010). Using mixed model analyses, shorter nighttime sleep duration was associated with any napping the next day, and any daytime napping was associated with less efficient sleep the same night. In a similar analysis of 235 older adults (mean age = 80.1 years), taking a longer nap during the day was associated with shorter sleep that night as determined by actigraphy, but in contrast to the findings of Owens et al. (2010), sleep duration did not predict next-day nap duration (Goldman et al., 2008). Given that adults may nap for different reasons than adolescents (e.g., more free time due to retirement, chronic illnesses), it is worthwhile to investigate whether temporal relationships between naps and nocturnal sleep are apparent in healthy adolescents.

The primary objective of the present study was to examine the temporal relationship between nocturnal sleep and daytime napping in healthy adolescents who participated in a week-long study of actigraphy and diary measures of sleep. We tested whether (a) shorter nocturnal sleep, lower sleep efficiency, and self-reported sleep quality predicted both the occurrence and duration of napping the following day; and (b) occurrence and duration of napping predicted shorter nocturnal sleep, lower sleep efficiency, and self-reported sleep quality that night. We also explored whether napping predicted a later bedtime, which would lead to shorter nocturnal sleep. A secondary objective was to describe the frequency and

duration of daytime naps in healthy adolescents, as well as potential differences in napping associations by race and gender.

METHODS

Study Design and Participants

A sample of 250 adolescents between the ages of 14 and 19 were enrolled from a single public high school near Pittsburgh, Pennsylvania, from November 2008 through May 2011 (excluding summers and school vacations). Adolescents were attending a public high school that served a lower- to middle-class community and was racially integrated. Participants were recruited from health classes for an adolescent health project designed to measure risk factors for cardiovascular disease and sleep. Approval of the research project was obtained from the school district superintendent, school principal, and the University of Pittsburgh Institutional Review Board. Participants (or parents or legal guardians for students under the age of 18) provided written informed consent prior to any research procedures. Assent was obtained for students under age 18. A parent or guardian verified the student was free of cardiovascular or kidney disease, and also not taking medications for emotional problems, diabetes, high blood pressure, or medications known to affect the cardiovascular system or sleep. In addition to the 250 students, 16 were ineligible to participate due to taking medication that could affect study variables, and 7 eligible students who signed consent did not begin the study. The final sample was 47% male and 56% White.

Protocol

Participants completed sleep diaries every morning and evening for one school week and weekend, simultaneous with actigraphy measures. They also completed sleep questionnaires and measures of cardiovascular risk. Testing for participants who were in organized sports was delayed until another semester. Testing also avoided school holiday breaks and the first few weeks or last few weeks of school because students were acclimating to their school schedules. Fourteen participants were excluded from analysis because of malfunctioning actigraph ($n = 1$) and less than five days and nights of diary data ($n = 13$), which we judged as necessary to obtain adequate measures of napping. These exclusions resulted in a final analytic sample of 236 participants. Additional information concerning the study procedure and actigraphy protocol can be found in Matthews, Hall, and Dahl (2014). Days on which the adolescent reported feeling ill were removed from analyses.

Measures

Actigraphy-assessed sleep—Actigraph devices are worn on the wrist and record movements and accelerations; using activity counts and diary records of bedtime and wake time, periods of sleep and wake can be estimated. The Mini-Mitter actiwatch model AW-16 (Philips Respironics, Bend, OR) was used to collect sleep-wake activity continuously over seven days and nights. Subjects were instructed to wear the watch on the nondominant arm and to press an event marker when they tried to go to sleep. Actigraphs were configured to collect data during 1-min epochs. Stored data were downloaded into the Actiware software program (version 5.57) for processing and analysis. The medium threshold (default) was selected to detect nocturnal sleep periods of at least 3 hr in duration based upon sleep onset

and offset using the 10-min criterion of quiescence. Nighttime rest periods were set using the data reported by the participant in their morning and evening sleep diaries as the time they “tried to go to sleep” and the “time they finally awoke.” Sleep periods occurring within 30 min of the major nocturnal sleep interval (either 30 min prior to sleeping or after waking) that were at least 15 min in duration were combined with the major sleep interval (i.e., if a 6-hr sleep interval was detected from 12 a.m. to 6 a.m., and a 20-min sleep interval was detected beginning at 11:30 p.m., the 20-min interval was combined with the major sleep interval. The new major sleep interval would become 11:30 p.m. to 6 a.m.). All subsequent sleep variables were then calculated from data within these set sleep periods. Sleep duration was calculated as actual sleep time from initial sleep onset to final sleep offset, excluding periods of wakefulness throughout the night. Sleep efficiency was calculated as the percentage of time attempting to sleep that was actually spent asleep. Given positive skew in the sleep efficiency data, natural log transformations were used in all analyses [$\ln(100 - \text{Efficiency} + 1)$], so that a high score reflected lower efficiency. The actiwatch has been used extensively in research studies, and has been validated against polysomnography measures for nocturnal sleep episodes (Kushida et al., 2001; Tryon, 2004).

Given that there is no accepted criterion for scoring actigraphy-assessed naps, we used the same criterion as for nocturnal sleep to designate periods of napping, that is, 10 min of quiescence; nap periods were measured in minutes. In a comparison of naps of at least 15 min in duration measured concurrently by actigraphy (using the medium threshold setting) and by polysomnography (PSG) in healthy adults aged 18 to 35 years, results suggested good accuracy, sensitivity, and specificity for the detection of nap and nonnap (resting wake) periods (Kanady, Drummond, & Mednick, 2011); the accuracy for nap and nonnap periods, respectively, was 85% and 77%. For the present study, actigraphy-assessed napping variables included the proportion of actigraphy-assessed nap days (total number of days with at least one nap divided by number of days with actigraphy data) and average minutes napped on napping days (e.g., 300 total min napped on 5 days that the adolescent took a nap = 60 min napped on napping days). Additionally, two actigraphy-assessed nap variables were used in all temporal analyses: total minutes napped each day, including days of no napping (e.g., 0 min napped on Day 1, 20 min napped on Day 2, and so on), and categorically assessed napping (yes/no a nap occurred that day). One actigraphy-assessed napping variable was positively skewed and underwent natural log transformation after adding 1 for use in temporal analyses (i.e., total minutes napped each day).

Daily diary-reported sleep—Adolescents completed a sleep diary on a handheld computer each morning after awakening. They rated sleep quality on a six-point scale based on two questions (“This morning I feel rested” and “My sleep last night was very good”), which were highly correlated, $r(236) = 0.76$, $p < .001$. Adolescents’ responses to the two questions were summed, with potential scores ranging from 2 to 12, with higher scores indicating increased sleep quality. Each night before going to bed, they reported the number of naps they took each day and the total number of minutes they spent napping in their diary.

Given that there is no accepted criterion for scoring diary-reported naps, the minimum length for accepted diary-reported naps was 10 min, in order to maintain consistency with actigraphy-assessed data. Diary-reported variables included (a) self-reported bedtime (i.e.,

the time the adolescent “tried to go to sleep”), (b) perceived sleep quality, (c) proportion of diary-reported napping days (total number of days with at least one nap divided by number of days with diary data, followed by square root transformation), and average minutes napped on diary napping days. In temporal analysis, two diary nap variables were used: total minutes napped each day (including nonnapping days, which were 0 min) and categorically assessed napping (yes/no a nap occurred that day). The variable for total minutes napped each day was positively skewed and underwent natural log transformation after adding 1.

Congruent napping periods—Actigraphy-assessed naps that began within 1 hr before or after a diary-reported nap were coded as “congruent.” This window was chosen to account for possible recall error in adolescents because of the lapse in time between daytime naps and completing the diary each night prior to bedtime, as well as the possibility that subjects may not recall actigraphy-assessed naps (which tended to be shorter; see Table 1). For congruent naps, the total minutes napped were based on the diary report. This method is similar to that used by Goldman and colleagues (2008), who set actigraphy-assessed nap intervals based on the stop and start time for the nap in the daily diary in a sample of elderly adults. In the present study, 2 congruent nap variables were used in temporal analyses: total congruent minutes napped each day (including nonnapping days) and categorically assessed congruent napping (yes/no a congruent nap occurred that day). The variable for total congruent minutes napped each day was positively skewed and underwent natural log transformation after adding 1.

Daytime sleepiness—Adolescents completed the daytime sleepiness subscale from the School Sleep Habits Survey for Adolescents (Wolfson & Carskadon, 1998). This subscale has 10 items measuring adolescents’ experiences of struggling to stay awake or falling asleep in various settings, including school and transportation, in the last two weeks. Participants rated their experiences from 1 to 4, with higher scores indicating greater daytime sleepiness; Cronbach’s $\alpha = 0.55$.

Demographic information—Adolescents self-reported age, gender, and race. Family socioeconomic status was determined from parental or caregiver report on the Hollingshead Four Factor Index (Hollingshead, 1975). This scale measures socioeconomic status by coding paternal and maternal years of education and highest attained degree, as well as current occupation for both parents (if contributing to the household income) to yield an overall score.

Statistical Analysis

Nocturnal sleep, napping, sociodemographic variables, and report of daytime sleepiness were examined in the full sample and by 2 (race) $\times$ 2 (gender) analysis of variance (ANOVA). Bivariate correlations were conducted between nocturnal sleep and napping variables.

To test temporal relationships between nocturnal sleep (actigraphy-assessed duration and efficiency; diary-reported quality) and (a) total minutes napped each day and (b) the occurrence of a nap that day (both by actigraph and diary report), multilevel random effects

mixed models were used to account for the nesting of assessments within subjects and across time. Additional analyses explored the relationship between napping (both total minutes napped and the occurrence of a nap) and same-day bedtime (i.e., diary-reported time the adolescent “tried to go to sleep”). Analyses were repeated for congruent naps and nocturnal sleep variables. All models used the maximum likelihood estimation method and the first-order auto-regressive error structure for the sequentially assessed sleep and napping data from the same individuals. Random-effects modeling with intercept and slope effects were used. Covariates included age, race, and gender. To explore whether the associations differed by subgroups classified by race or gender, additional analyses tested the interactions between race or gender and each napping and sleep variable. The p values were considered statistically significant at $< .05$.

RESULTS

Sample Characteristics

The analytic sample was composed of 62 Black males, 70 Black females, 48 White males, and 56 White females. Their average age was approximately 16 years (Table 1). The sample was from low to middle class, as evidenced by their family Hollingshead scores (range 10 to 54); Black adolescents had higher family Hollingshead scores, relative to Whites. There were no significant race or gender differences with regard to adolescents’ ratings of daytime sleepiness.

Nocturnal Sleep and Napping Characteristics

On average, adolescents slept 6.5 hr at night and demonstrated sleep efficiency values above 80%, as assessed by actigraphy (Table 1). As reported elsewhere based on the full sample (Matthews et al., 2014), Black adolescents and males had shorter nocturnal sleep duration and less efficient sleep, relative to White adolescents and females for actigraphy measures. Average actigraphy-assessed 24-hr sleep for the full sample was 7.0 hr, with males and Black adolescents demonstrating significantly less 24-hr sleep, relative to females and White adolescents. The self-reported sleep quality for the full sample was 8.3 (on a 12-point scale), with females reporting significantly lower nocturnal sleep quality than males.

Napping was a common behavior (Table 1). Eighty-nine percent had at least one actigraphy-assessed nap and 62% reported at least one diary-assessed nap. Adolescents napped on average 36% (range = 0–100%) of the days by actigraphy and 18% (range = 0–86%) of the days by diary. On average, actigraphy-assessed naps were 65 min in duration, while diary-reported naps were 140 min. More adolescents napped on school days than on weekends (by both methods; data not shown). Females had more days with at least one nap, as measured by both actigraphy and diary, and also demonstrated longer average lengths of naps (by actigraphy only), relative to males. No racial differences in frequency or length of naps emerged.

Across the week, the longer the average nocturnal sleep duration measured by actigraphy, the higher the sleep efficiency, the smaller the proportion of days napped by actigraphy and diary, the shorter the naps by diary only on napping days, and the lower the sleepiness (Table

2). Nocturnal sleep efficiency across the week was unrelated to actigraphy or diary napping variables. Proportion of days napped and length of naps on napping days were related by actigraphy, but highly correlated by diary report. Better self-reported nocturnal sleep quality was associated with a smaller proportion of days napped by both actigraphy and diary report, but was unrelated to average length of naps on napping days (by either method). Naps estimated by actigraphy and diary were correlated, although, as noted above, their means and proportions were quite different. Daytime sleepiness was unrelated to the proportion of days napped (by actigraphy or diary) but was related to napping longer on napping days as measured by actigraphy, but not by diary report.

Nocturnal Sleep Predicting Next-Day Napping

We tested whether decreased nocturnal sleep duration, efficiency, and quality would predict next-day nap duration and occurrence. As shown in Table 3, decreased actigraphy-assessed nocturnal sleep duration predicted increased next-day nap duration as measured by actigraphy and diaries. Poorer perceived sleep quality predicted increased next-day diary-reported minutes napping, but not actigraphy-recorded nap minutes. Poorer sleep efficiency did not predict next-day napping by actigraphy or diary. The pattern of results was identical when temporal analyses involved nocturnal sleep variables predicting the occurrence of a nap (yes/ no) the following day. As shown in Table 3, decreased nocturnal sleep duration predicted next-day occurrence of napping (yes/no) by both actigraphy and diary. Decreased nocturnal sleep quality was associated with the next-day occurrence of a nap by diary, but not by actigraphy. Poorer sleep efficiency was unrelated to occurrence of a nap by actigraphy or diary. Analyses involving nocturnal sleep variables predicting congruent nap minutes and nap occurrence demonstrated an identical pattern to actigraphy and diary results; results shown in Table 3.

Napping Predicting Nocturnal Sleep

We tested whether increased minutes napping (actigraphy-assessed and diary-reported) would predict decreased same-day actigraphy-assessed sleep duration and efficiency, as well as self-reported quality. As shown in Table 4, increased actigraphy-assessed and diary-reported nap duration were associated with decreased same-day nocturnal sleep duration and sleep efficiency. In contrast, napping (by actigraphy or diary report) did not predict same-day nocturnal sleep quality. The same pattern of results was found when the occurrence of a nap (yes/no) was used to predict same-day nocturnal sleep. The occurrence of a nap by both actigraphy and diary predicted decreased same-day actigraphy-assessed nocturnal sleep duration and sleep efficiency, but not sleep quality. Analyses involving congruent nap minutes and nap occurrence predicting nocturnal sleep variables demonstrated an identical pattern to actigraphy and diary results; results shown in Table 4.

Exploratory Analyses

We explored whether nap duration and the occurrence of a nap were associated with later bedtimes. Increased nap duration by actigraphy ($B[SE] = .09[0.02]$, $p < 0.001$), as well as whether a nap occurred that day ($B[SE] = .36[0.08]$, $p < 0.001$) were associated with later same-day diary-reported bedtime. In contrast, both diary-reported nap duration and occurrence were unrelated to same-day diary-reported bedtime.

Second, we evaluated whether the relationships between nocturnal sleep and napping variables differed by gender or race. Of the 48 analyses conducted, two were significant. Results demonstrated a significant interaction of race and nocturnal sleep quality on actigraphy-assessed nap duration ($B[SE] = -.09[0.04]$, $p = 0.02$) and nap occurrence ($B[SE] = .13[0.04]$, $p < 0.05$), such that White adolescents who reported better sleep quality in their morning diary demonstrated decreased nap duration and nap occurrence that day.

DISCUSSION

Given the known deficits in adolescent nocturnal sleep duration, it is surprising that few studies have investigated daytime napping in this population, particularly in relationship to nocturnal sleep. In a sample of adolescents who slept on average significantly less than the recommended 9 hr per night, our results suggest daytime napping is a prevalent behavior. Eighty-nine percent of adolescents demonstrated at least one actigraphy-assessed nap and 62% reported at least one diary-assessed nap during the week-long study period. Adolescents napped on about one third of the days, as assessed by actigraphy, and on about one fifth of days, as assessed by sleep diaries.

A temporal relationship emerged between short nocturnal sleep duration leading to more daytime napping and vice versa, measured either by actigraphy or by diary. Furthermore, the pattern of results was largely confirmed by congruently measured naps, which lends confidence to our individual findings based on actigraphy and diaries. The observed temporal relationship between nocturnal sleep duration and daytime naps is consistent with results in middle-aged adults from Owens et al. (2010). Results also partially replicate the work of Goldman et al. (2008), who found that actigraphy-assessed napping predicted shorter nocturnal sleep in elderly adults, but did not find a relationship between sleep duration and next-day napping. To our knowledge, this is the first study that has examined the temporal relationship between nocturnal sleep and daytime napping in adolescents.

The two-process model of sleep (Borbély, 1982), which identifies processes of homeostatic sleep drive and circadian rhythms, provides a theoretical rationale for why daytime napping may impact nocturnal sleep, and vice versa. For adolescents who do not obtain adequate nocturnal sleep on a given night, sleep drive should be higher at the start of the next day, relative to the start of days after they have more adequate sleep. In response to higher sleep drive, individuals may nap to alleviate fatigue and sleepiness, which is consistent with our results and those of Owens et al. (2010). The two-process model may also be relevant to the extent that daytime napping may, theoretically, decrease homeostatic sleep drive, leading to a later bedtime and decreased sleep efficiency, as found in the present study and in Owens et al. (2010). This is noteworthy when one considers that adolescents have a tightly constrained wake time due to mandatory early school start times, and thus have little ability to extend their sleep time on school nights.

We also found that poor sleep quality reported in the morning diary was more consistently related to measures of diary-reported napping, relative to measures of actigraphy-assessed napping. Given that participants reported sleep quality and napping in their morning and evening diaries respectively, it makes sense that sleep quality would be more related to a

self-reported measure than a behavioral (i.e., actigraphy) measure of napping, perhaps because of common reporting bias.

We explored whether subgroups, that is, Blacks/Whites or males/females, showed different temporal relationships for nocturnal sleep to napping or vice versa. Our data do not support variation in the temporal relationships by race or gender.

Although there were modest correlations between actigraphy and diary measures of napping *and* both measures were related to nocturnal sleep variables, as previously mentioned, these variables had notably different means and standard deviations. It appears that diary naps reflect fewer and longer nap episodes, whereas actigraphy-assessed naps reflect more frequent and shorter nap episodes. When analyses were constrained to actigraphy-assessed naps with a congruent diary nap, the pattern of results was similar to that found with actigraphy-assessed or diary-reported naps alone. This might suggest that the length of naps may not be as important for nocturnal sleep duration, efficiency, or quality, as the mere *occurrence* of a nap (regardless of measurement method) that day. Moreover, it is likely that diary and actigraphy methods obtain somewhat different information about napping. For example, adolescents may have reported naps in their diaries only on days when they perceived feeling more tired or less rested than normal. Daily diary naps may also represent purposeful nap behavior, such as escaping and managing emotions, or perhaps planned, preventive naps taken prior to anticipated short nocturnal sleep (e.g., staying up late doing homework). In contrast, actigraphy may capture a broader range of nap behavior, including planned and also unplanned naps that may have spontaneously occurred in response to sleepiness, which may explain why more actigraphy-assessed naps were captured, but they were of shorter duration. Additionally, since napping is a behavior that typically occurs with less regularity than nocturnal sleep, it might have been more difficult for participants to track, especially since they completed the diaries at night prior to bedtime rather than online throughout the day. When using diaries to assess naps in future studies, it may be worthwhile to provide specific categories (i.e., *Do you nap at least 30 minutes a day?*), to make recall more accessible. Ecological momentary assessment throughout the day may also more reliably capture self-reports of napping behaviors.

It is important to note that there are some limitations associated with the use of actigraphy. Actigraphy has been validated against polysomnography (Kushida et al., 2001; Tryon, 2004), which is considered the gold standard of sleep assessment, but it is still limited by its reliance on measurement of accelerations and movements (Van Wouwe, Valk, & Veenstra, 2011). Although we cannot be certain that some periods that were recorded as sleep were actually still moments during wakefulness, while reading or watching TV, for example, our findings are strengthened by the similarity of results for actigraphy and diary estimates of napping, which were supported by data from congruently measured naps. Additionally, it should be noted that the internal reliability for the daytime sleepiness measure was somewhat low in this sample, and thus results related to daytime sleepiness should be interpreted with caution. Yet this study also had a number of strengths. These include an ethnically diverse population and relatively even distributions of race and gender; multimodal assessment of sleep, involving actigraphy-assessed nocturnal sleep and daytime

naps in combination with self-report measures (sleep diary and questionnaire); and examination of temporal associations among nocturnal sleep and daytime napping.

To our knowledge, the present study is the first to investigate the temporal relationship between daytime napping and nocturnal sleep in healthy adolescents, using a combination of methods and an improved analytic approach relative to previous studies. Data from the present study indicate that a temporal relationship exists between daytime napping and nocturnal sleep and that daytime napping in healthy adolescents is associated with decreased nocturnal sleep duration. These findings are strengthened by the examination of congruently measured nap periods, which provided a similar pattern of results to those demonstrated by actigraphy or diary alone. Future studies are warranted to study napping, as present results suggest it is an important factor to monitor in order to obtain a more complete picture of sleep in adolescents. Ultimately, although napping may make up for insufficient nocturnal sleep in the short term, frequent napping may interfere with nocturnal sleep in adolescents, and, in turn, may have implications for adolescent mental and physical health.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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TABLE 1

Sample Characteristics by Race and Gender

Mean (SD) unless noted	Total sample	Black		White	
		Male	Female	Male	Female
<i>N</i> (%)	236	62 (26.3)	70 (29.7)	48 (20.3)	56 (23.7)
Age, years	15.7 (1.30)	15.7 (1.23)	15.6 (1.36)	15.7 (1.50)	15.6 (1.12)
Family Hollingshead Total ^a	30.4 (11.40)	33.5 (11.78)	30.9 (11.42)	29.0 (11.59)	27.7 (10.29)
<i>Actigraphy measures</i>					
Nocturnal sleep duration, hours ^{a,b}	6.5 (0.8)	6.2 (0.8)	6.3 (0.6)	6.5 (0.7)	6.9 (0.9)
Nocturnal sleep efficiency, % ^{a,b}	82.8 (4.8)	81.2 (5.4)	82.6 (4.8)	83.2 (3.8)	84.4 (4.5)
24-hour sleep, hours ^{a,b}	7.0 (0.9)	6.6 (0.8)	6.9 (0.6)	6.9 (0.7)	7.5 (1.1)
<i>N</i> (%) of nappers	211 (89.4%)	51 (82%)	65 (93%)	42 (88%)	53 (95%)
Proportion of days with at least one nap ^b	.35 (.22)	.31 (.22)	.43 (.23)	.31 (.22)	.35 (.21)
Average minutes napped per napping days ^b	65.5 (41.2)	58.6 (39.8)	74.9 (36.1)	54.4 (43.6)	69.3 (44.5)
<i>Diary measures</i>					
Sleep quality (<i>M, SD</i>) ^b	8.3 (1.7)	8.9 (1.5)	8.0 (1.9)	8.4 (1.6)	7.8 (1.7)
<i>N</i> (%) of nappers	146 (62%)	32 (52%)	54 (77%)	23 (48%)	37 (66%)
Proportion of days with at least one nap ^b	.18 (.19)	.13 (.17)	.22 (.18)	.14 (.18)	.21 (.21)
Average minutes napped per napping days	140.0 (78.5)	142.3 (94.6)	147.1 (70.5)	129.8 (96.9)	134.1 (61.9)
<i>Questionnaire</i>					
Sleepiness (<i>M, SD</i>)	16.0 (3.7)	15.9 (4.0)	16.3 (3.5)	15.3 (3.8)	16.3 (3.4)

Note. Sleepiness = daytime sleepiness subscale from the School Sleep Habits Survey for Adolescents.

^aRace main effect from ANOVAS, $p < .05$.

^bGender main effect from ANOVAS, $p < .05$.

TABLE 2

Correlations Among Questionnaire Measures and Sleep Variables

	1	2	3	4	5	6	7
<i>Actigraphy</i>							
1. Nocturnal duration, hours							
2. In_efficiency	-.38***						
3. Average min napped per napping day	-.08	.01					
4. Prop. days napped across the full week	-.22**	.01	.31*				
<i>Diary</i>							
5. Quality	.02	.02	-.03	-.13*			
6. Average min napped per napping day	-.15*	.09	.46***	.29***	-.11		
7. Prop. days napped across the full week_sqrt	-.18**	.04	.35***	.41***	-.20**	.65***	
<i>Questionnaire</i>							
8. Sleepiness	-.17***	-.05	.19**	.09	-.11	-.09	.04

Note. Sleep efficiency is reverse scored so that a high score indicates less efficiency. Prop. days napped = proportion of days with at least one nap across the full week. Sleepiness = daytime sleepiness subscale from the School Sleep Habits Survey for Adolescents.

*
 $p < .05$

**
 $p < .01$

 $p < .001$.

TABLE 3

Nocturnal Sleep Variables Predicting Next-Day Nap Minutes and Nap Occurrence by Actigraphy and Diary

Nocturnal predictors	Napping outcomes					
	Actigraphy naps		Diary naps		Congruent naps	
	Minutes	Occurrence (Y/N)	Minutes	Occurrence (Y/N)	Minutes	Occurrence (Y/N)
Duration, hours (by actigraphy)	-.15 (.03) ***	-.20 (.05) ***	-.09 (.03) **	-.17 (.04) ***	-.10 (.03) **	-.23 (.05) ***
Efficiency (by actigraphy)	-.02 (.13)	-.01 (.14)	.14 (.14)	.03 (.18)	.12 (.11)	.17 (.21)
Quality (by diary)	-.03 (.02)	-.00 (.03)	-.07 (.02) ***	-.11 (.03) ***	-.06 (.02) **	-.11 (.03) ***

Note. Values represent: Unstandardized estimate (Standard error). Sleep efficiency is reverse scored so that a high score indicates less efficiency. Analyses adjusted for age, race, and gender in mixed models.

* $p < .05$

** $p < .01$.

*** $p < .001$.

TABLE 4

Actigraphy-Assessed and Diary-Reported Nap Minutes and Occurrence Predicting Same-Night Nocturnal Sleep Variables

Napping predictors	Nocturnal outcomes		
	Duration, hours (by actigraphy)	Efficiency (by actigraphy)	Quality (by diary)
Actigraphy naps			
Minutes	-.12 (.02) ***	.01 (.01) **	-.02 (.03)
Occurrence (Yes/No)	-.39 (.09) ***	.05 (.02) **	-.06 (.14)
Diary naps			
Minutes	-.09 (.03) ***	.01 (.01) *	-.03 (.03)
Occurrence (Yes/No)	-.45 (.11) ***	.05 (.02) *	-.12 (.17)
Congruent naps			
Minutes	-.15 (.03) ***	.01 (.01) *	-.05 (.04)
Occurrence (Yes/No)	-.74 (.12) **	.06 (.03) *	-.25 (.20)

Note. Values represent: Unstandardized estimate (Standard error). Sleep efficiency is reverse scored so that a high score indicates less efficiency. Analyses adjusted for age, race, and gender in mixed models.

*
 $p < .05$

**
 $p < .01$.

 $p < .001$.