

# Sleep in Healthy Black and White Adolescents

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## KEY WORDS

adolescence, gender, health behaviors, race, sleep

## ABBREVIATIONS

ANOVA—analysis of variance

CDC—Centers for Disease Control and Prevention

SES—socioeconomic status

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**WHAT'S KNOWN ON THIS SUBJECT:** A national probability study based on time diaries for 2 days indicated that black and white adolescents get close to the recommended amount of sleep. Sleep should be measured by using multiple methods to get an accurate picture of adolescent sleep.



**WHAT THIS STUDY ADDS:** Based on actigraphy and daily diary assessments, healthy adolescents from a lower socioeconomic community got less than the recommended amount of sleep; black male students were likely to have short, fragmented sleep, which may play a role in their health risks.

## abstract



**BACKGROUND AND OBJECTIVES:** Inadequate sleep among adolescents has negative consequences for self-regulation, emotional well-being, and risk behaviors. Using multiple assessment methods, we evaluated the adequacy of sleep among healthy adolescents from a lower socioeconomic community and expected differences by race.

**METHODS:** A total of 250 healthy high school students enrolled in public school (mean age: 15.7 years; 57% black, 54% female) from families of low to middle class according to the Hollingshead scale participated in weeklong assessments of sleep duration and fragmentation, assessed by using actigraphy; sleep duration and perceived quality, assessed by using daily diaries; and daytime sleepiness and sleep delay, assessed by using a questionnaire.

**RESULTS:** Students slept during the school week a mean  $\pm$  SD of  $6.0 \pm 0.9$  hours per night according to actigraphy and  $6.8 \pm 1.1$  hours according to daily diary, and during the weekend, a mean of  $7.4 \pm 1.2$  and  $8.7 \pm 1.4$  hours, respectively. Black participants and male participants slept less and had more fragmented sleep; female participants reported poorer quality of sleep in their daily diaries and more daytime sleepiness. The results remained significant after adjustments for age, physical activity, smoking status, and percentile BMI.

**CONCLUSIONS:** Most students slept less than the 8 to 9 hours suggested by the guidelines of the Centers for Disease Control and Prevention. Black male participants had the least amount of sleep, which may play a role in the substantial risks experienced by this demographic group. Our findings are consistent with recommendations that pediatricians should routinely screen their adolescent patients about their sleep, especially those from at-risk subgroups. *Pediatrics* 2014;133:e1189–e1196

Adolescence is a period of intense growth and physical development, including changes in circadian regulation.<sup>1,2</sup> There is a circadian shift (delay) in adolescence, resulting in a biologically based tendency to stay up later and sleep later when possible. Although laboratory studies suggest that the need for sleep does not decline during the pubertal transition,<sup>3</sup> time spent sleeping on school nights typically does decrease from childhood through adolescence.<sup>4</sup> As such, students accumulate a sleep debt during the school week that is due, in part, to the mandatory early start times of high schools.<sup>5</sup> In 1 survey of 3000 adolescents based on random digit dialing, the average reported difference between weekend and weekday sleep was ~2 hours, and daytime sleepiness was reported by 45%.<sup>6</sup> In the 2007 Centers for Disease Control and Prevention (CDC) National Youth Risk Behavior Survey of 12 154 high school students, 39% reported  $\leq 6$  hours of typical sleep on school nights.<sup>7</sup>

A more optimistic view of adolescent sleep was recently published.<sup>8</sup> In a large, nationally representative sample with 3 waves, older children (with caregivers' assistance as needed) reported in time diaries their sleep duration on 1 weeknight and 1 weekend night. Using sophisticated weighted sampling techniques, a median estimate for total sleep duration for 14- to 18-year-olds was ~9 hours a day, a value within the CDC guidelines for 8.5 to 9.5 hours of sleep for 10- to 17-year-olds ([www.cdc.gov/features/sleep](http://www.cdc.gov/features/sleep) March 2013). As with other surveys, estimates for median sleep were shorter on the weekday than on the weekend. No gender or racial or ethnic differences were observed.

Although many adolescents may obtain adequate sleep, it is also clear that a substantial proportion of adolescents are obtaining less sleep (ie, below the

median estimates based on time diaries). Adolescents who live in disadvantaged communities or who are disadvantaged by virtue of their minority status are faced with challenges that may result in different sleep patterns than estimated according to national data. In a separate article based on the 2002 wave of data from the sample of Williams et al,<sup>8</sup> black adolescents reported in their time diaries less sleep during the weekday and weekend than white adolescents.<sup>9</sup> Other large survey and diary studies have shown that black children and adolescents have shorter sleep times than white participants but report fewer symptoms of insomnia.<sup>9–11</sup> These findings are consistent with meta-analyses documenting that African American adults have shorter, less efficient sleep but fewer insomnia symptoms than do white adults.<sup>12,13</sup> African American adults may also have shorter free-running circadian rhythms than white adults.<sup>14</sup>

Sleep is a complex behavioral and biological phenomenon, and it can be characterized by not only the duration of sleep but also whether it is fragmented, with frequent awakenings; perceived as low quality; or leads to difficulty staying awake during the day. These dimensions of sleep can be estimated by using a diary as well as by using actigraphy, polysomnography, and standardized questionnaires; they are modestly correlated.<sup>15</sup> Laboratory-based measures of sleep reduce the variation in the sleep environment, which increases the reliability of sleep measurements but also reduces the external validity of the measures. Self-report measures of sleep are often examined with regard to a long interval of time (eg, last 3 months) or their "typical" pattern; however, some dimensions of sleep can vary markedly from night to night.<sup>16</sup> Time diaries of activities and sleep throughout 24 hours require compliant, conscientious

participants. The dynamic and changing nature of adolescence, coupled with marked changes in sleep and circadian rhythms during adolescence, suggests that a multimethod approach to assessing sleep is necessary to obtain a comprehensive picture of adolescents' sleep.

The present article describes sleep duration assessed by using actigraphy and self-report diaries, fragmentation assessed by using actigraphy, diary reports of perceived sleep quality, and standardized questionnaire measures of sleep problems and daytime sleepiness in a sample of healthy black and white high school students. Actigraphy and diary measures were collected across 1 school week, including weekends and weekdays; this time frame is necessary to obtain reliable estimates of adolescent sleep duration.<sup>17</sup> The students were from a lower socioeconomic status (SES) community and thus were at high risk for many of the school, home, and neighborhood challenges present in these communities. We hypothesized that adolescents, especially those from low SES communities, would not get adequate sleep and that black participants would have less adequate sleep than white participants as measured estimated by actigraphy and diary findings.

## METHODS

### Participants

A sample of 250 adolescents between the ages of 14 and 19 years were enrolled from a single public high school from November 2008 through May 2011 (except for summers and school vacations). This high school served ~500 students (42% black, 56% white, and 2% other); 63% were eligible for free or reduced lunch, compared with 26% statewide. In the 3 years of the study, the high school graduated 83%; district performance was ranked as 111 of 123 high schools in western Pennsylvania.

This school was selected because it was racially integrated; served a lower to middle SES community, maximizing the potential for SES to be similar for black and white students; and allowed us to evaluate the effects of race, independent of SES. The study was described to potential participants during regularly scheduled high school physical/health education classes as concerning the relationships among stress, sleep, and cardiovascular risk factors. Approval of the research project was obtained from the school district superintendent, school principal, and the institutional review board of the University of Pittsburgh. Participants (or parents/ legal guardians for students aged <18 years) provided written informed consent before any research procedures were initiated. Sixteen students were ineligible for the study on the basis of the following exclusionary criteria: medication use for emotional or psychological disorders, diabetes, blood pressure, or any medication known to affect the cardiovascular system or sleep. The final sample was 46% male and 43% non-black (primarily white, with 2 white Hispanic students).

## Measures

### Sleep

We selected measures of the key dimensions of sleep that could be assessed in an ambulatory sample of adolescents.<sup>18</sup> The Mini-Mitter Actiwatch model AW-16 (Philips Respironics, Bend, OR) was used to assess behavioral indices of sleep/wake activity continuously over 7 days and nights. Actigraphs were configured to collect data during 1-minute 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 hours in duration

based on sleep onset and offset using the 10-minute criteria. Sleep periods occurring within 30 minutes of the major nocturnal sleep interval (either 30 minutes before sleeping or after waking) that were at least 15 minutes in duration were combined with the major sleep interval (ie, if a 6-hour sleep interval was detected from 12:00 AM–6:00 AM, and a 20-minute sleep interval was detected beginning at 11:30 PM, the 20-minute interval was combined with the major sleep interval, with the new major sleep interval becoming 11:30 PM–6:00 AM). All subsequent sleep variables were then calculated from data within these set sleep periods. Total sleep time was calculated as the time spent asleep between initial sleep onset and final sleep offset, excluding periods of wakefulness throughout the night. Sleep fragmentation, a measure of restlessness during sleep, was calculated as ([%1-minute intervals of movement during sleep + % 1-minute intervals of immobility] divided by total 1-minute immobility intervals). It was highly correlated in our sample with minutes awake during the sleep interval after sleep onset ( $r = 0.77$ ,  $P < .0001$ ). The actigraph has been widely used in research studies and has been validated against polysomnographic measures in the clinic.<sup>19,20</sup>

A diary measure of total sleep time was calculated based on the time participants estimated they were in bed trying to go to sleep to the time they awakened in the morning minus self-reported sleep latency and time awake during the night. Perceived sleep quality was based on the sum of 2 ratings in the morning diary: “This morning I feel rested” and “My sleep last night was very good.” Each statement was rated as “NO!, NO, no, yes, YES, YES!” NO! was the lowest score and YES! was the highest score; scores could range from 2 to 12. Participants also reported naps

and estimated total minutes napping each day in their diaries.

The nights before vacation days during the school week were considered to be weekends, and Sunday night was considered to be a school night. Sleep data were averaged across the total week, school nights only, and weekend/nonschool nights only. Given that weekend sleep of at least 2 hours more than on a weekday may be a useful marker of sleep debt,<sup>21</sup> we also calculated for each participant whether the average across school nights was at least 2 hours less than the average across weekend/nonschool nights.

Two subscales of the Sleep Habits Survey<sup>21</sup> were completed. The sleep delay subscale consists of 6 items assessing the frequency of behaviors indicative of erratic or delayed sleep-wake patterns in the past 2 weeks; for example, arrived late to class because of oversleeping or stayed up past 3:00 AM. Participants rated the frequency of each behavior on a scale ranging from 1 (never) to 5 (every day/night) and were totaled to yield a score ranging from 6 to 30. The daytime sleepiness subscale consisted of 10 items regarding situations in which the students may have struggled to stay awake or fallen asleep in the past 2 weeks (eg, attending a performance, in class at school, driving a car). These situations were rated on a 4-point scale (no, struggled to stay awake, fallen asleep, or both struggled to stay awake and fallen asleep); the findings were totaled to get a score ranging from 10 to 40. Both subscales were analyzed as continuous variables.

### Demographic Characteristics

Age, gender, and race/ethnicity were determined according to adolescent report; other family measures were determined by interview of the parent or guardian, except for 6 parents/guardians who moved, refused, or were

in jail. Paternal and maternal education was coded in years and in highest attained degree. Current occupation for both parents (if contributing to the household income) was coded into modified Hollingshead categories and combined with educational attainment to yield an overall score (the higher the score, the higher the SES).<sup>22</sup> Parental marital status was coded as a dichotomous variable, with parents/guardians married or living together versus single-parent or guardian.

### Health Behaviors

The Youth Risk Behavior Survey from the CDC's 2007 guidelines asked: "During the past 7 days, on how many days were you physically active at least 60 minutes per day?" and "During the past 30 days, on how many days did you smoke cigarettes?"<sup>23</sup> Students who reported not smoking in the last 30 days were considered to be non-smokers. Height was measured by using a stadiometer, and weight was measured on a Tanita digital scale (Tanita Corporation of America, Inc, Arlington Heights, IL). BMI was determined by using the National Heart, Lung, and Blood Institute's online calculator and computed as a percentile against national norms according to age and gender; it was analyzed as a continuous variable.<sup>24</sup>

### Statistical Analysis

Missing data were as follows: 1, no actigraphy (due to equipment malfunction); 3, no sleep diaries; 4, no questionnaires; and 6, no family Hollingshead SES scores. Because preliminary analyses found that the Hollingshead SES score was unrelated to the sleep variables in univariate and multivariate models, this covariate was removed from the multivariate analysis to conserve a larger sample size. Sample size for the sleep variables were as follows: 249 participants for

actigraphy measures, 247 for diary weekday measures, 243 for diary weekend measures, and 246 for sleep questionnaires in unadjusted analyses; 238 to 244 were assessed in adjusted analyses.

Variables were examined for skewness and kurtosis. Fragmentation scores ranged from 11.1 to 78.5 for the full week and were transformed by  $\log(X + 1)$ . Other sleep variables had normal distributions. BMI was transformed by the square root of  $(100 - \text{BMI percentile})$ .

Variations according to race and gender were analyzed according to 2 (gender)  $\times$  2 (race) analysis of variance (ANOVA) for continuous variables and according to 2 (gender)  $\times$  2 (race) logistic regression for categorical outcomes. Interrelationships among sleep characteristics were evaluated by using the Pearson correlation. Because duration of sleep during the school nights and weekend were found to be unrelated, these factors were examined separately in the following analyses. Sleep characteristics were initially evaluated by using a 2 (gender)  $\times$  2 (race) ANOVA (with no adjustments). Multivariate linear regression analyses were then conducted, in which age, gender, race, self-rated physical activity, current smoker, and BMI percentile were entered to address whether univariate sleep differences according to gender and race remained significant after adjustment for covariates. *P* values were considered statistically significant at  $<.05$  (2-tailed).

## RESULTS

### Sample Characteristics

The sample was composed of 66 black male participants, 76 black female participants, 50 white male participants, and 58 white female participants. Their mean age was  $<16$  years (Table 1). The sample was from a low-to middle-class community as evidenced by their family Hollingshead

scores (range: 10–54). Approximately 60% of the participants were from single-parent families. Overall, the sample was relatively heavy compared with national norms, but they reported being physically active approximately one-half of the days in the past week. Approximately one-quarter were smokers in the last 30 days.

Black participants were more likely to be from families with slightly higher Hollingshead scores, whereas white participants were more likely to be from 2-parent households. Males and blacks were more physically active than females and whites, respectively. The only variable that yielded a significant interaction of race and gender was percentile BMI; white female participants had the lowest BMI percentile.

### Associations Among Sleep Measures

Sleep characteristics were somewhat overlapping (Table 2). Shorter sleep according to actigraphy and diary reports was strongly related. The shorter the sleep according to actigraphy results, the more fragmented the sleep. Diary assessment of sleep quality was unrelated to other sleep variables. Greater sleep delay and daytime sleepiness scores were related modestly to shorter sleep. Weekday and weekend sleep fragmentation was highly correlated ( $r = 0.64, P < .001$ ), as was weekday and weekend perceived sleep quality ( $r = 0.53, P < .001$ ). Sleep durations on the weekend and weekday were unrelated whether estimated by using actigraphy or diary reports ( $r = 0.07$ ).

### Sample Sleep Characteristics

Participants' nocturnal sleep was short in duration during the school week, whether estimated by actigraphy or diary reports (Table 3). It has been suggested that  $\geq 495$  minutes of sleep on a weeknight is adequate, whereas

**TABLE 1** Sample Characteristics

Characteristic	Black		White		Total Sample (N = 250)
	Male (n = 66)	Female (n = 76)	Male (n = 50)	Female (n = 58)	
Age, y	15.7 ± 1.21	15.7 ± 1.38	15.7 ± 1.48	15.6 ± 1.12	15.7 ± 1.30
Family Hollingshead score <sup>a</sup>	33.5 ± 11.96	30.5 ± 11.48	29.04 ± 11.47	27.6 ± 10.18	30.3 ± 11.46
Single-parent household, n (%) <sup>a</sup>	44 (67.7)	52 (71.2)	21 (42.9)	32 (56.1)	149 (61.1)
Percentile BMI, median (IQR) <sup>b</sup>	87.5 (30)	89 (26)	89 (26)	83.5 (42)	88 (31)
Days physically active ≥60 min in last week <sup>a,c</sup>	4.4 ± 2.3	3.2 ± 2.3	3.9 ± 1.9	2.6 ± 2.1	3.5 ± 2.3
Smokers in last 30 d, n (%) <sup>a</sup>	15 (23.1)	14 (18.7)	19 (38.8)	20 (35.1)	68 (27.6)

Unless otherwise noted, data are presented as mean ± SD. IQR, interquartile range.

<sup>a</sup> Race main effect from ANOVAs or logistic regression,  $P < .05$ .

<sup>b</sup> Race × gender interaction from 2 (race) × 2 (gender) ANOVA,  $P < .05$ .

<sup>c</sup> Gender main effect,  $P < .05$ .

≤405 minutes is short.<sup>21</sup> In our sample, according to actigraphy, 2% of adolescents had, on average, adequate sleep during the week and 66% short sleep; by diary report, 19% had, on average, adequate sleep during the week and 22% short sleep. As measured according to actigraphy and diary reports, respectively, 34.5% and 42.0% of participants exhibited sleep debt. Participants reported better sleep quality in their diaries on the weekend than on weekdays. The mean scores for daytime sleepiness were in the normal range for high school students; the sleep delay scores were somewhat higher.

### Short Sleep Duration and Fragmented Sleep

Black students had shorter sleep estimated by actigraphy and more fragmented sleep than white students across the full week. Table 3 presents unadjusted means and results of 2 × 2 ANOVAs. Black participants' shorter sleep was apparent on both weekdays and weekends, with white female participants having the longest sleep across the week as estimated by using actigraphy. Black students reported shorter sleep in their diaries for the weekday and across the full week than did white students; there were no differences according to race for sleep duration reported in the diary on

the weekend. Male participants had shorter and more fragmented sleep than female participants.

In the multivariate models that included age, BMI percentile, smoker, and physical activity (standardized  $\beta$  coefficients) (Table 4), black male participants had shorter sleep overall and during the week. Black participants had shorter sleep on the weekend, relative to white participants and a race-by-gender interaction for weekend sleep showed white female participants having the longest sleep duration. Black students had more fragmented sleep than white students, independent of covariates.

**TABLE 2** Correlations Among Sleep Characteristics

Characteristic	Actigraphy			Fragmentation	Diary Self-Report			Questionnaire Sleep Delay	
	Duration				Duration				Quality
	Total	Weekday	Weekend		Total	Weekday	Weekend		
<b>Actigraphy</b>									
Duration									
Weekday	0.81 <sup>a</sup>								
Weekend	0.57 <sup>a</sup>	0.07							
Fragmentation	-0.28 <sup>a</sup>	-0.16 <sup>a</sup>	-0.27 <sup>a</sup>						
<b>Diary</b>									
Duration									
Total	0.58 <sup>a</sup>	0.51 <sup>a</sup>	0.27 <sup>a</sup>	0.00					
Weekday	0.52 <sup>a</sup>	0.68 <sup>a</sup>	-0.03	0.03	0.84 <sup>a</sup>				
Weekend	0.24 <sup>a</sup>	-0.06	0.58 <sup>a</sup>	-0.04	0.53 <sup>a</sup>	0.07			
Quality	0.01	0.05	-0.07	0.07	0.06	0.09	-0.03		
<b>Questionnaires</b>									
Sleep delay	-0.13 <sup>b</sup>	-0.13 <sup>b</sup>	-0.03	0.10	-0.14 <sup>b</sup>	-0.18 <sup>c</sup>	-0.02	-0.05	
Daytime sleepiness	-0.16 <sup>b</sup>	-0.14 <sup>b</sup>	-0.11	0.02	-0.18 <sup>a</sup>	-0.24 <sup>a</sup>	-0.06	-0.08	

Total refers to full week.

<sup>a</sup>  $P < .001$ .

<sup>b</sup>  $P < .05$ .

<sup>c</sup>  $P < .01$ .

**TABLE 3** Sleep Characteristics of Sample

Characteristic	Black		White		Total (N = 249)
	Male (n = 66)	Female (n = 75)	Male (n = 50)	Female (n = 58)	
<b>Actigraphy</b>					
Duration, h					
Total <sup>a,b</sup>	6.2 ± 0.8	6.3 ± 0.6	6.4 ± 0.7	6.9 ± 0.9	6.4 ± 0.8
Weekday <sup>a,c</sup>	5.7 ± 0.8	5.9 ± 0.8	6.0 ± 0.8	6.4 ± 1.0	6.0 ± 0.9
Weekend <sup>a</sup>	7.3 ± 1.0	7.2 ± 1.4	7.3 ± 1.3	7.9 ± 1.1	7.4 ± 1.2
Sleep debt ≥2 h, n (%)	22 (33.3)	28 (37.3)	14 (28.0)	22 (37.9)	86 (34.5)
<b>Fragmentation, median (IQR)<sup>d</sup></b>					
Total <sup>a,c</sup>	32.5 (13.4)	29.3 (16.6)	26.9 (9.0)	25.6 (11.3)	28.7 (13.0)
Weekday <sup>a,c</sup>	32.9 (13.4)	28.9 (18.9)	26.2 (9.4)	26.7 (9.6)	28.5 (14.0)
Weekend <sup>a</sup>	34.1 (13.6)	30.7 (17.1)	28.5 (11.6)	26.4 (11.7)	29.7 (14.9)
<b>Diary self-report</b>					
Duration, h					
Total <sup>a</sup>	7.4 ± 0.9	7.2 ± 0.9	7.5 ± 0.8	7.7 ± 1.0	7.4 ± 0.9
Weekday <sup>a</sup>	6.7 ± 1.1	6.6 ± 1.1	7.0 ± 1.0	7.1 ± 1.2	6.8 ± 1.1
Weekend	8.7 ± 1.4	8.4 ± 1.6	8.7 ± 1.2	8.9 ± 1.4	8.7 ± 1.4
Sleep debt ≥2 h, n (%)	27 (41.5)	33 (45.2)	18 (37.5)	24 (42.1)	102 (42.0)
<b>Sleep quality (diary)<sup>d</sup></b>					
Total <sup>c</sup>	8.9 ± 1.6	8.0 ± 1.9	8.4 ± 1.6	7.7 ± 1.8	8.2 ± 1.8
Weekday <sup>c</sup>	8.5 ± 1.9	7.7 ± 2.1	8.1 ± 1.6	7.4 ± 2.0	7.9 ± 2.0
Weekend <sup>c</sup>	9.6 ± 1.9	8.7 ± 2.2	9.1 ± 1.8	8.5 ± 2.1	9.0 ± 2.1
<b>Questionnaires</b>					
Sleep delay <sup>d</sup>	12.9 ± 4.2	14.3 ± 4.8	13.4 ± 3.9	13.4 ± 4.3	13.5 ± 4.4
Daytime sleepiness <sup>c,d</sup>	15.9 ± 3.9	16.4 ± 3.7	15.3 ± 3.7	16.3 ± 3.4	16.0 ± 3.7

Total refers to full week. Unless otherwise noted, data are presented as mean ± SD. IQR, interquartile range.

<sup>a</sup> Race main effect, *P* < .05.

<sup>b</sup> Race × gender interaction from 2 (race) × 2 (gender) ANOVA, *P* < .05.

<sup>c</sup> Gender main effect, *P* < .05.

<sup>d</sup> See methods section for units of measure.

### Reports of Worse Sleep

Female participants reported in their diaries worse sleep quality overall, whereas black and white participants reported equal levels of sleep quality; Table 3 presents the unadjusted means

and results of 2 × 2 ANOVAs. Female participants' lower quality sleep ratings were apparent during the weekend and weekdays. Female students also reported more daytime sleepiness. There were no differences in sleep delay scores.

In multivariate models that included age, BMI percentile, smoker, and physical activity (standardized  $\beta$  coefficients) (Table 4), female students reported worse sleep quality over the week and more daytime sleepiness than male students; there were no race effects in these sleep variables.

**TABLE 4** Standardized Coefficients (SEs) for Race (Black = 1, White = 0) and Gender (Female = 1, Male = 0) From Multivariate Regression Models Predicting Sleep Characteristics

Characteristic	Black		Female		<i>R</i> <sup>2</sup> (Full Model)
	$\beta$ (SE)	<i>P</i>	$\beta$ (SE)	<i>P</i>	
<b>Actigraphy</b>					
Duration					
Total	−0.27 (0.06)	<.001	0.14 (0.06)	.03	0.12
Weekday	−0.22 (0.06)	<.001	0.14 (0.07)	.04	0.09
Weekend	−0.13 (0.06)	.05	0.05 (0.07)	.43	0.06
Total fragmentation	0.27 (0.06)	<.001	−0.12 (0.07)	.06	0.09
<b>Diary</b>					
Duration					
Total	−0.16 (0.06)	.01	−0.07 (0.07)	.30	0.07
Weekday	−0.13 (0.07)	.05	−0.06 (0.07)	.41	0.04
Weekend	−0.06 (0.07)	.33	−0.08 (0.07)	.26	0.05
Total quality	0.09 (0.07)	.15	−0.20 (0.07)	<.001	0.06
<b>Questionnaires</b>					
Sleep delay	0.04 (0.07)	.55	0.11 (0.07)	.10	0.05
Daytime sleepiness	0.03 (0.07)	.66	0.14 (0.07)	.04	0.05

Covariates: smoker, transformed BMI percentile, age, and physical activity. Total refers to full week.

### DISCUSSION

Our study provided evidence regarding: (1) adolescents' nocturnal sleep characteristics across 1 school week in a low- to middle-class sample; (2) whether gender and race differences in sleep characteristics emerged; and (3) whether the race and gender differences were accounted for by health behaviors. We found that students slept on average 6.4 hours per night as measured by using actigraphy and 7.4 hours as measured by self-report diaries across a 1-week period of time. On school nights, sleep duration was even

shorter: 6.0 hours as measured by using actigraphy and 6.8 hours as measured according to diary reports. Furthermore, using the definition of sleep debt as obtaining  $\geq 2$  hours of sleep on the weekend nights (relative to the weeknights), 35% and 42% experienced sleep debt as estimated by using actigraphy and diary reports, respectively. The adolescents rated their sleep quality as moderately positive in their diaries, especially on the weekends.

Compared with normative sleep duration based on time diaries reported by Williams et al<sup>8</sup>, our sample slept at approximately the 10th to 25th percentile. Differences in findings are likely due to differences in method and frequency of assessment of sleep duration, inclusion/exclusion of periods of awakening during the night, and the nature of the samples. Our sample was based on healthy adolescents enrolled in a single high school serving a low- to middle-class community selected because of its multiethnic representation, whereas the sample of Williams et al was a national probability sample. Other large survey studies have also reported that many adolescents do not get the recommended amount of sleep, especially during the school week. For example, among  $>3000$  public high school students, 26% reported getting  $<6.5$  hours of sleep per school night.<sup>21</sup> In the Youth Risk Behavior Survey of high school students in 50 states and Washington, DC, 69% reported getting  $<8$  hours of sleep on an average school night.<sup>7</sup> In the Teen Health 2000 Study of 4175 youth aged 11 to 17 years, 20% reported typical sleep of  $\leq 6$  hours on weeknights.<sup>25</sup>

Our study produced several striking findings regarding differences in sleep according to race and gender. Black students had shorter nocturnal sleep duration based on both actigraphy and diary reports as well as more fragmented sleep based on actigraphy,

relative to white students. Black male participants had the shortest sleep, whereas white female participants had the longest sleep, differing by a mean of 42 minutes during the week. These results were independent of age, BMI percentile, and health behaviors in multivariate linear regression models. Female students reported worse sleep quality in their diaries and more daytime sleepiness. The race differences are consistent with some other studies based on survey and diary assessments, and extend previous research on actigraphy-assessed indices of sleep duration and fragmentation.<sup>9–11</sup> Taken together, the evidence suggests that black male adolescents may be the demographic subgroup most vulnerable to the negative consequences of inadequate sleep.

Although the purpose of our study was not to investigate the associations among the sleep measures, our findings nevertheless point to the multidimensional nature of sleep. Those with shorter sleep duration measured according to actigraphy and diary reported more daytime sleepiness and sleep delay in the last 2 weeks. Surprisingly, adolescents' daily ratings of perceived sleep quality were unrelated to other dimensions of sleep. The sleep duration estimate according to diary reports and actigraphy were substantially correlated probably due to the way the diaries were used to define the potential sleep interval. Similar correspondence between diary and actigraphy was reported among 12 adolescents and 54 children in an Australian sample.<sup>26</sup> Taken together, this pattern shows the utility of measuring multiple aspects of sleep and that different measures measuring the same sleep characteristic can yield different estimates.

The study has a number of limitations and strengths. Regarding limitations, the study design was cross-sectional,

and antecedent-consequent relationships could not be described. Second, because our study recruited high school students from a district that serves a low- to middle-class community, the findings cannot be generalized to adolescents from higher SES communities. Third, the sleep measures did not include polysomnography to characterize sleep apnea or sleep stages; we only had a parental screen for symptoms of sleep-disordered breathing. However, the study did have several strengths; the sample was diverse and was composed of black and white adolescents male and female, who were screened for health status. Second, the measures of sleep were detailed and appropriate for testing high school students in a school/home setting. They were measured across a sufficient number of nights to obtain a reliable assessment of the participants' sleep. Thus, we believe our sleep measures provide a valid picture of the students' sleep patterns across a full school week and weekend.

## CONCLUSIONS

In an editorial accompanying the article by Williams et al,<sup>8</sup> Jenni<sup>27</sup> noted the substantial variability of sleep duration among children and adolescents as well as that it is not clear what is considered adequate sleep for optimal health and functioning. Optimal or adequate sleep is indeed difficult to define, but it is apparent that less sleep (self-reports of typical sleep  $\leq 6$  hours) is associated with more negative cognitive, behavioral, and functional measures among adolescents in cross-sectional and longitudinal analyses.<sup>25,28,29</sup> Furthermore, in the CDC study of 12 154 high school students, those who reported having  $<8$  hours of sleep during a school night also reported feeling sad or hopeless and engaging in multiple adverse health behaviors, including smoking, and alcohol and

marijuana use.<sup>7</sup> There also may be physiologic consequences of short, fragmented sleep. In the present study sample of healthy teenagers, we previously reported that shorter sleep is associated with higher 24-hour ambu-

latory blood pressure and insulin resistance.<sup>30,31</sup> We think it is premature to conclude that adolescents are getting sufficient sleep (particularly those from some sociodemographic subgroups), and considering the variation

in estimates of sleep duration by different methods of assessment. It is important to routinely query adolescents regarding their sleep patterns and hygiene to promote better sleep health.

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