Self-Regulation and Sleep Duration, Sleepiness, and Chronotype in Adolescents

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abstract

OBJECTIVE: To determine whether shorter school-night sleep duration, greater daytime sleepiness, and greater eveningness chronotype were associated with lower self-regulation among adolescents.

METHODS: An online survey of 7th- to 12th-grade students in 19 schools in Fairfax County, Virginia Public Schools was conducted in 2015. Self-regulation was measured with the Behavior Rating Inventory of Executive Function, 2nd edition, Screening Self-Report Form. Sleep measures included school night-sleep duration (hours between usual bedtime and wake time), daytime sleepiness (Sleepiness Scale in the Sleep Habits Survey, tertiles), and chronotype (Morningness–Eveningness Scale for Children, continuous score and tertiles). Sociodemographic factors and mental health conditions were analyzed as potential confounders.

RESULTS: Among 2017 students surveyed, the mean age was 15.0 years (range, 12.1–18.9 years), and 21.7% slept <7 hours on school nights. In regression models adjusted for confounders, there was a significant independent association between self-regulation and both chronotype ($P < .001$) and daytime sleepiness ($P < .001$) but not sleep duration ($P = .80$). Compared with those in the lowest tertile of daytime sleepiness, those in the highest tertile had lower (0.59 SD units; 95% confidence interval, 0.48–0.71) self-regulation, as did those in the eveningness tertile of chronotype compared with those in the morningness tertile (0.35 SD units lower; 95% confidence interval, 0.24–0.46).

CONCLUSIONS: Among adolescents, greater daytime sleepiness and greater eveningness chronotype were independently associated with lower self-regulation, but shorter sleep duration was not. Aspects of sleep other than school-night sleep duration appear to be more strongly associated with self-regulation.

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Dr Owens helped design the data collection instruments and procedures, conceptualized and designed the analyses in this study, drafted sections of the manuscript (Introduction and Discussion), and made critical revisions to the manuscript; Dr Dearth-Wesley managed the data and conducted the statistical analyses, assisted Dr Whitaker in the development of the manuscript tables and figures, and made critical revisions to the manuscript; Dr Lewin helped design the data collection instruments and procedures, participated in the data collection, and made critical revisions to the manuscript; Dr Gioia provided expert guidance on the application of the self-regulation measures and made critical revisions to the manuscript; Dr Whitaker helped design the data collection instruments and procedures, conceptualized and designed the

WHAT'S KNOWN ON THIS SUBJECT: Chronic sleep loss in adolescents has been linked to impaired self-regulation and increased risk of adverse health and functional outcomes. However, less is known about how self-regulation is related to daytime sleepiness and circadian phase preference (chronotype).

WHAT THIS STUDY ADDS: Among adolescents, daytime sleepiness and a more "eveningness" chronotype (ie, tendency for later sleep onset and offset and timing of activity patterns) are both stronger predictors of poor self-regulation than is short nighttime sleep duration.

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Insufficient sleep has reached epidemic levels among adolescents in the United States[1–7] and in other nations.[8–12] Chronic sleep loss in teenagers is now considered a public health problem by leading advocates for children's health, including the American Academy of Pediatrics,[13] the American Medical Association,[14] and the US Department of Health and Human Services,[15] because of its potential adverse impacts on adolescent cardiometabolic health,[16–19] mental health,[20–24] substance use,[25–27] safety,[28–33] and academic performance.[34,35]

Impaired self-regulation may be 1 mechanism by which insufficient sleep leads to adverse effects on health and functioning. Self-regulation is the "act of managing cognition and emotion to enable goal-directed actions such as organizing behavior, controlling impulses, and solving problems constructively."[36] Three interrelated domains are involved in self-regulation: cognitive (eg, executive functioning and goal setting), emotional (eg, emotional awareness and management), and behavioral (eg, impulse control and delay of gratification). Self-regulation is governed by a number of brain regions such as the prefrontal cortex, amygdala, and ventral striatum, which are undergoing profound developmental changes during adolescence[37,38] and whose function is adversely affected by insufficient sleep.[39–41]

Short-term experimental sleep manipulation in young children,[42,43] school-age children,[44,45] and adolescents[46] acutely affects self-regulation and the performance of complex tasks. Although impaired self-regulation has also been observed in the context of "naturalistic" chronic sleep loss, on a level experienced by many adolescents, there is some evidence that the relationship between sleep and functional impairments related to poor self-regulation involves more than insufficient sleep. For example, chronotype, or circadian-based morningness–eveningness preference (ie, the tendency to be a "morning lark" or "night owl") is another aspect of sleep regulation that may independently influence self-regulation. A pronounced shift to a more evening chronotype coincides both with increased age and pubertal development in adolescents.[47–50] Given that evening types cannot easily fall asleep earlier at night and must still meet societal demands to wake up and function early in the morning, this often results in a sleep duration that is insufficient to meet sleep needs. Moreover, timing of activity and alertness patterns during the day are also shifted later in these people. This misalignment of circadian biology and societal demands has been called "social jet lag."[51,52] Eveningness is also a risk factor in adolescents for a number of conditions that have also been associated with poor self-regulation: emotional and behavioral problems,[53–56] substance abuse,[57] obesity,[58] health risk behaviors,[52,59,60] and lower school performance.[61–64] These findings suggest that a broader conceptualization of deficient sleep in adolescents that involves problematic timing and duration of sleep may be a useful construct in assessment of functional outcomes such as impaired self-regulation.

Finally, 2 cross-sectional studies of adolescents found that self-regulation was associated with daytime sleepiness (an increased propensity to fall asleep in inappropriate circumstances and difficulty maintaining alertness, which interferes with activities of daily living) but not nighttime sleep duration.[65,66] However, neither study examined the contribution of chronotype to self-regulation.

The purpose of this study was to determine whether 3 distinct aspects of sleep, nighttime sleep duration, daytime sleepiness, and chronotype, were independently associated with self-regulation in a large community-based sample of middle and high school students. We secondarily examined the relationship between these dimensions of sleep and 3 domains of self-regulation: cognitive, emotional, and behavioral.

METHODS

To determine how nighttime sleep duration, daytime sleepiness, and chronotype predict self-regulation, we used data from an online survey of students (grades 7–12) and parents, which was conducted between March and June 2015 in Fairfax County Public Schools. Fairfax is the 11th largest school district in the United States, serving a diverse community in the northern Virginia suburbs of Washington, District of Columbia.

Survey Design

The survey was made available to all students (and their parents) in 19 schools: 8 of 23 middle schools (grades 7–8), 8 of 24 high schools (grades 9–12), and all 3 secondary schools (grades 7–12). The 19 schools were selected to be representative of the entire district with regard to student race and ethnicity and family income. The survey design addressed the need to protect class time (no in-class administration), minimize disruptions (no direct e-mail or cell phone contact with students by the research team), and obtain parent consent. Parents (or primary caregivers) at each of the study schools received an initial invitation to participate in the study via a district-sponsored e-mail, followed by 3 reminders. Parents were asked to grant electronic consent for their child to participate and to complete an online parent survey. Students with parental consent were sent a link via e-mail to a separate online student survey. Upon completion of the survey, students were given a $5 gift card to Amazon.

We received 2020 complete student surveys from the ~34 800 students enrolled in the 19 schools (6%). We excluded from our analysis 1 student age <12.0 years and 2 students >19.0 years, leaving a final sample of 2017 students. Compared with the overall population of students in grades 7 to 12 in the district, those in our sample were more often non-Hispanic white (60.7% vs 42.1%) and less often receiving free or reduced-price school meals (8.1% vs 27.4%). Study procedures were approved by the school district's Research Screening Committee and the institutional review boards at the Children's National Medical Center and Temple University.

Self-Regulation

Self-regulation, our study outcome, was measured with the validated Behavior Rating Inventory of Executive Function, second edition, Screening Self-Report Form, consisting of 12 statements about behaviors.[67] Students were asked whether they "had problems with these behaviors over the last 6 months" and were given the response options of "never" (1), "sometimes" (2), or "often" (3). In addition to a total self-regulation score (Executive Function Screening score), 3 distinct subscores were generated: cognitive self-regulation, which has 6 items dealing with the facets of working memory (eg, "I forget instructions easily"), task completion (eg, "I have difficulty finishing a task on my own"), and planning or organizing (eg, "I don't plan ahead for school assignments"); emotional self-regulation, which has 4 items dealing with the facets of shifts (eg, "It bothers me when I have to deal with changes") and control (eg, "I get upset over small events"); and behavioral, which has 2 items dealing with the facet of inhibition (eg, "I am impulsive").[67] Item scores were reverse-coded so that higher scores reflected greater self-regulation. The total score and the 3 subscores, each with a possible range from 1 to 3, were calculated by adding across the constituent items and dividing by the number of items. In our sample, the internal consistency measures (Cronbach's α) of the total score and the cognitive, emotional, and behavioral subscores were 0.85, 0.80, 0.71, and 0.65, respectively. The total self-regulation score and 3 subscores had statistically normal distributions.

Sleep Duration

Nighttime sleep duration on school nights was calculated from student responses to separate questions about usual bedtime on school nights and wake time on school days. Sleep duration was calculated as the difference in hours between these times after we excluded 27 cases with either implausible bedtimes (<7 PM or >3 AM), wake times (<3 AM or >8:30 AM), or calculated duration (<4 or >12 hours). Sleep duration (hours) had a statistically normal distribution and was used in our primary analysis as a continuous variable.

Chronotype

Chronotype was assessed with the 10-item Morningness–Eveningness Scale for Children.[50] The scale, adapted from circadian rhythm questionnaires for adults,[68–70] is designed to assess the phase of the day, on a continuum from morningness to eveningness, in which adolescents prefer to engage in various cognitive and physical activities. The scale generates possible scores from 10 to 43, with higher scores indicating greater morningness. In our sample, the Cronbach's α of the scale was 0.79. The chronotype scores had a statistically normal distribution, and the score was used in our primary analysis as a continuous variable. There are no established cutoff points for defining morningness or eveningness on this scale.[71] To facilitate the interpretation of our findings, additional analyses were conducted with the scores divided into tertiles: morningness (>28), intermediate (25–28), and eveningness (<25).

Daytime Sleepiness

Self-reported daytime sleepiness was assessed with a modified version of the 10-item Sleepiness Scale in the Sleep Habits Survey.[72–74] Students were asked whether, during the last 2 weeks, they had "struggled to stay awake or fallen asleep" in 10 situations. We replaced 2 situations ("traveling in a bus, train, plane or car" and "attending a performance") with 2 others ("during a study hall or free period" and "during lunch at school"). Our modified response options were "never" (0), "Yes, I struggled to stay awake" (1), and "Yes, I fell asleep" (2). Students could also indicate that the situation did not apply to them during the last 2 weeks. A total possible score between 0 and 2 was calculated by summing across the items (situations) and dividing the number of items and situations that applied to the student. Higher sleepiness scores meant greater daytime sleepiness. The Cronbach's α of the modified scale was 0.77. Responses on the scale were skewed toward low sleepiness, with 28.1% scoring 0 (never sleepy during any of the situations). Therefore, scores were divided into 3 tertiles of sleepiness: low (0 to ≤0.1), medium (>0.1 to <0.4), and high (≥0.4).

Covariates

Data were obtained on potential confounding variables from the student survey, the parent survey, and electronic administrative records from the school district. Students reported their race and Hispanic ethnicity in separate questions. These data were merged into a 5-category race/ethnicity variable. Those reporting >1 race were placed in the "other" category, and those reporting Hispanic ethnicity, regardless of race designation, were classified as Hispanic. Students also reported whether they had any "disabilities or chronic illnesses," including 2 mental health conditions: depression and attention-deficit/hyperactivity disorder. Students could also name other disabilities or chronic illnesses. Those naming anxiety disorders (eg, posttraumatic stress disorder) or other mood disorders (eg, bipolar disorder) were grouped, along with those reporting depression, into a single group called "anxiety and/or mood disorder." Each parent respondent provided information on his or her own educational level and that of his or her spouse or partner. The school district provided data (yes/no) on student qualification for free or reduced-price school meals (household income ≤185% of the federal poverty guideline[75]), sex, and birth date (used to calculate age).

Data Analysis

Correlation coefficients were used to examine bivariate relationships between the 3 exposures (sleep duration, sleepiness, and chronotype). Each self-regulation measure was used as a dependent variable in multivariable linear regression analyses. Missing data were imputed for all study variables, and no systematic patterns of missing data were identified.[76] In Stata (Stata Corp, College Station, TX),[77] we used sequential regression imputation[78] to create 20 imputed data sets, each with 2017 cases.[79] Our imputation model included all 7 covariates, along with the self-regulation outcomes and key exposures (sleep duration, sleepiness, and chronotype). We then ran linear regression models on the imputed data sets, and the reported model parameters were aggregated across data sets.[80] All 3 sleep variables were examined together in each model to determine their independent association with self-regulation, both with and without adjustment for all covariates. In models containing all covariates, we evaluated 2-way and 3-way interactions between the 3 sleep variables and between age and each sleep variable. Because multiple interactions were evaluated for each self-regulation outcome, a P value of <.01 was considered a statistically significant interaction.

RESULTS

The mean age of the 2017 students was 15.0 (range 12.1–18.9) years, and 54.4% were in grades 9 to 12. Nearly 90% of students had at least 1 parent or primary caregiver who had completed college, and <10% qualified for free or reduced-price school meals (Table 1). In contrast to the 2016 American Academy of Sleep Medicine consensus recommendations for optimal sleep duration in 13-18 year olds (8-10 hours),[81] 21.7% reported a usual school-night sleep duration <7 hours.

Correlations between sleep duration, sleepiness, and chronotype were all statistically significant ($P < .001$), reflecting greater daytime sleepiness among those with shorter sleep duration (Spearman $r = -0.42$) and those with greater eveningness preference (or lower chronotype score) (Spearman $r = -0.44$). Students with greater eveningness preference had shorter sleep duration (Pearson $r = 0.34$).

In linear regression models with self-regulation measures as the dependent variables and adjustment for all covariates, both sleepiness and chronotype were statistically significant ($P \leq .001$) independent predictors of self-regulation (Table 2). However, in none of these models was sleep duration (in hours) significantly associated with self-regulation after we controlled for sleepiness and chronotype. This was also true when sleep duration

TABLE 1 Participant Characteristics

Characteristics	Mean (SD) or No. (%)[a]
Total self-regulation score, mean (SD)[b]	2.29 (0.41)
Cognitive self-regulation subscore, mean (SD)	2.30 (0.48)
Emotional self-regulation subscore, mean (SD)	2.24 (0.49)
Behavioral self-regulation subscore, mean (SD)	2.39 (0.56)
School-night sleep duration, h, mean (SD)	7.71 (1.22)
Chronotype score, mean (SD)	26.71 (5.18)
Daytime sleepiness, no. (%)	
Low sleepiness (score ≤0.1)	660 (34.9)
Medium sleepiness (score >0.1 to <0.4)	604 (31.9)
High sleepiness (score ≥0.4)	629 (33.2)
Age, y, no. (%)	
12	203 (10.1)
13	456 (22.6)
14	417 (20.7)
15	341 (16.9)
16	311 (15.4)
17	222 (11.0)
18	67 (3.3)
Sex, no. (%)	
Female	1095 (54.3)
Male	922 (45.7)
Race/ethnicity, no. (%)	
Non-Hispanic white	1224 (60.7)
Non-Hispanic black	121 (6.0)
Hispanic, any race	186 (9.2)
Non-Hispanic Asian	259 (12.8)
Non-Hispanic other race	227 (11.3)
Highest parental education, no. (%)	
Higher than master's	340 (17.8)
Master's or some graduate school	950 (49.8)
College graduate	392 (20.6)
Some college or technical degree	154 (8.1)
High school diploma or less	70 (3.7)
Free or reduced-price meals, no. (%)	
No	1853 (91.9)
Yes	164 (8.1)
Anxiety or mood disorder, no. (%)	
No	1857 (93.7)
Yes	125 (6.3)
Attention-deficit/hyperactivity disorder, no. (%)	
No	1765 (89.1)
Yes	217 (10.9)

[a] $N = 2017$. Participants were missing data on characteristics as follows: total self-regulation (183), cognitive self-regulation (172), emotional self-regulation (159), behavioral self-regulation (160), sleep duration (129), chronotype (108), sleepiness (124), parental education (111), anxiety or mood disorder (35), and attention-deficit/hyperactivity disorder (35).

[b] Before the reverse coding of items, the mean (SD) values for the self-regulation outcomes (total score and cognitive, emotional, and behavioral subscores) were 1.71 (0.41), 1.70 (0.48), 1.76 (0.49), and 1.61 (0.56), respectively.

TABLE 2 Linear Regression Models Predicting Self-Regulation

	Model 1[a]			Model 2[b]		
	B	95% Confidence Interval	*P*	*B*	95% Confidence Interval	*P*
Outcome 1: Total self-regulation						
Intercept	2.09	1.93 to 2.25	<.001	2.22	1.93 to 2.51	<.001
School-night sleep duration, h	−0.01	−0.03 to 0.01	.17	−0.00	−0.02 to 0.02	.80
Chronotype, score	0.02	0.01 to 0.02	<.001	0.01	0.01 to 0.02	<.001
Medium sleepiness	−0.15	−0.19 to −0.10	<.001	−0.14	−0.19 to −0.10	<.001
High sleepiness	−0.26	−0.30 to −0.21	<.001	−0.24	−0.29 to −0.20	<.001
R^2		0.14			0.25	
Outcome 2: Cognitive self-regulation						
Intercept	1.95	1.77 to 2.14	<.001	2.28	1.94 to 2.62	<.001
School-night sleep duration, h	−0.00	−0.02 to 0.02	.80	0.00	−0.02 to 0.02	.84
Chronotype, score	0.02	0.01 to 0.02	<.001	0.02	0.01 to 0.02	<.001
Medium sleepiness	−0.15	−0.20 to −0.10	<.001	−0.15	−0.20 to −0.10	<.001
High sleepiness	−0.29	−0.35 to −0.24	<.001	−0.29	−0.34 to −0.24	<.001
R^2		0.15			0.26	
Outcome 3: Emotional self-regulation						
Intercept	2.13	1.93 to 2.33	<.001	2.28	1.91 to 2.65	<.001
School-night sleep duration, h	−0.01	−0.04 to 0.01	.22	−0.01	−0.03 to 0.02	.55
Chronotype, score	0.01	0.01 to 0.02	<.001	0.01	0.01 to 0.02	<.001
Medium sleepiness	−0.16	−0.21 to −0.10	<.001	−0.14	−0.20 to −0.09	<.001
High sleepiness	−0.26	−0.32 to −0.20	<.001	−0.21	−0.27 to −0.15	<.001
R^2		0.08			0.15	
Outcome 4: Behavioral self-regulation						
Intercept	2.41	2.18 to 2.64	<.001	1.94	1.50 to 2.38	<.001
School-night sleep duration, h	−0.03	−0.06 to −0.01	.005	−0.01	−0.03 to 0.02	.68
Chronotype, score	0.01	0.01 to 0.02	<.001	0.01	0.00 to 0.01	.001
Medium sleepiness	−0.12	−0.19 to −0.06	<.001	−0.14	−0.20 to −0.07	<.001
High sleepiness	−0.15	−0.22 to −0.08	<.001	−0.17	−0.24 to -0.10	<.001
R^2		0.03			0.10	

All models are based on a sample size of 2017, with multiple imputation used to account for missing data. Higher self-regulation scores indicate greater self-regulation. Sleep duration is modeled in hours (continuous); chronotype is modeled as a score (continuous), with higher scores indicating greater morningness preference; sleepiness is modeled as categories (tertiles), with lowest tertile (low sleepiness group) omitted.

[a] Model 1 contains the 3 sleep variables but no covariates.

[b] Model 2 is adjusted for 7 covariates: age, sex, race or ethnicity, highest parental education, receipt of free or reduced-price meals, anxiety or mood disorder, and attention-deficit/hyperactivity disorder.

was modeled as a binary (<7 and ≥7 hours) or 4-category (<7, 7 to <8, 8 to <9, and ≥9 hours) variable. The difference in total self-regulation score, expressed in SD units, between those with high and low sleepiness was 0.59 (95% confidence interval, 0.48–0.71), after we adjusted for covariates, chronotype score, and sleep duration (in hours). The difference in standardized total self-regulation score between those with eveningness and morningness chronotype was 0.35 (95% confidence interval, 0.24–0.46), after we adjusted for covariates, level of sleepiness, and sleep duration (in hours).

When interaction terms were added to our regression models, none of the interactions were statistically significant. Specifically, the relationship between self-regulation and each of the sleep variables did not significantly differ by age. In groups with either shorter (<7 hours) or longer (≥7 hours) sleep duration, the relationship between self-regulation and sleepiness (Fig 1) was similar, as was the relationship between self-regulation and chronotype (Fig 2).

DISCUSSION

To our knowledge this is the first study to examine sleep duration, sleepiness, and chronotype in relation to self-regulation in a large community-based sample of adolescents. Our findings suggest that eveningness chronotype and increased daytime sleepiness are associated with self-regulation but that short sleep duration is not.

These findings contrast with those from short-term experimental studies in adolescents showing that sleep restriction impairs self-regulation.[82–87] However, those studies differ from larger epidemiologic studies, such as ours, which assessed the relationship between self-regulation and chronic sleep loss, based on usual nighttime sleep duration. Our findings are consistent with the only 2 other epidemiologic studies on this topic, both of which also showed no significant association among adolescents between sleep duration and aspects of self-regulation. Among 236 US adolescents, daytime sleepiness, but not nighttime sleep duration, predicted parent-reported deficits in executive function[65]; among 1194 Argentinian adolescents, sleep duration was not significantly associated with attention after accounting for daytime sleepiness.[66] However, neither study examined the role of chronotype.

An emerging literature suggests that eveningness chronotype (circadian preference) is associated with behaviors involving impaired self-regulation, such as drug and alcohol use, and unsafe behaviors and sexual practices.[26,88] Eveningness is also associated with risk taking in the domains of financial, ethical, and recreational decision-making.[89] Furthermore, associations between chronotype, health risk behaviors, and well-being are strongest in adolescents and young adults.[51]

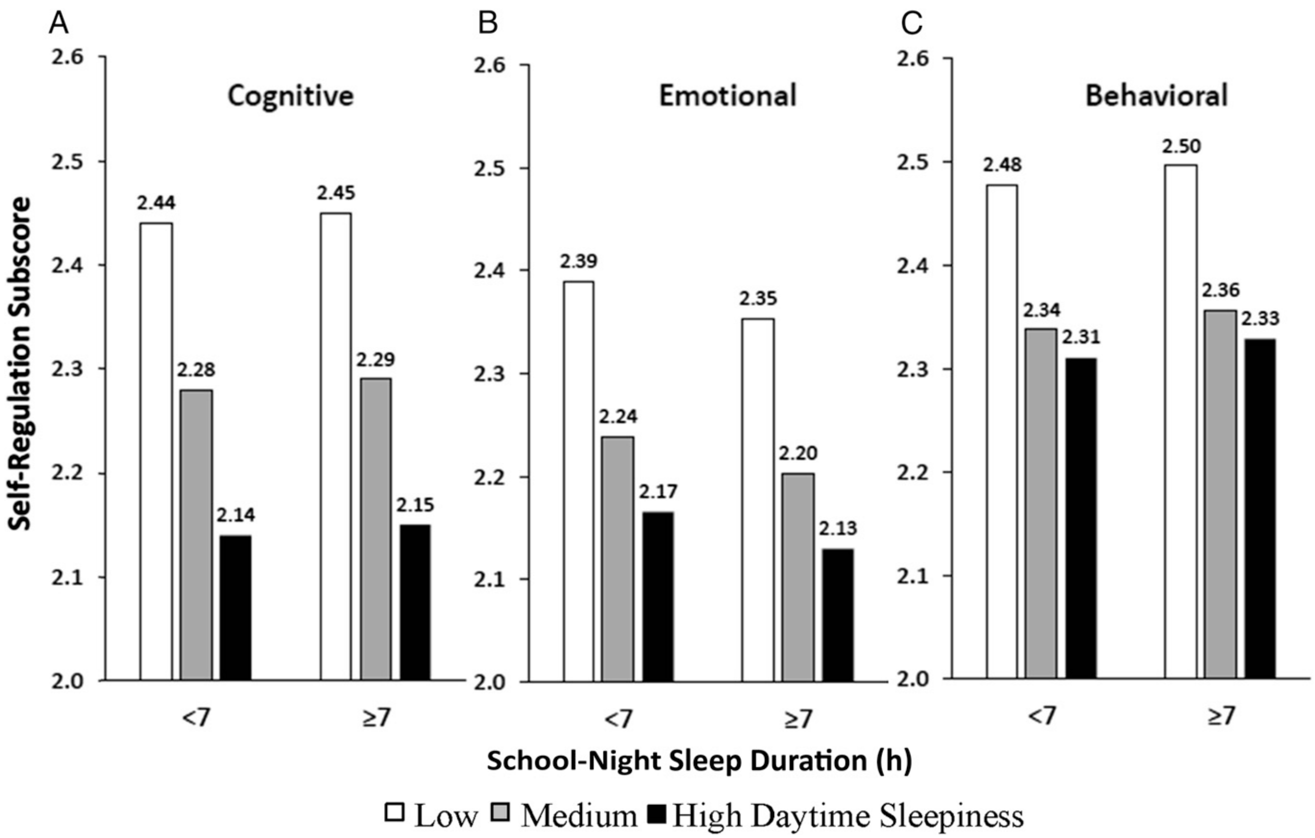

FIGURE 1

Adjusted mean self-regulation subscores by school-night sleep duration and daytime sleepiness. Group mean self-regulation subscores are adjusted for chronotype and 7 covariates (age, sex, race or ethnicity, highest parental education, receipt of free or reduced-price meals, anxiety or mood disorder, and attention-deficit/hyperactivity disorder) and after multiple imputation of missing data (*N* = 2017).

There are several possible explanations for this association. One is that evening types sleep less because of their later bedtimes and social and environmental demands necessitating early morning wake times. These people are also forced to awaken and function at a time of day that, for them, occurs during their biological lowest level of alertness (circadian nadir). Evening types are also more likely to be exposed to environmental factors (eg, increased late evening light and decreased morning light), which exacerbate the biologically based eveningness preference. In addition, throughout the day, circadian-based peaks and troughs of alertness in evening types may not coincide (or synchronize) with timing of environmental demands (eg, test taking and homework times).[47,90,91] Thus, among evening-type adolescents the misalignment of environmental expectations with circadian biology may contribute to actual and perceived impairment in self-regulation. Furthermore, when given the opportunity on weekends and non–school or work days, evening types tend to revert to their normal sleep pattern of late bedtimes and wake times, which typically results in variability in sleep patterns over the course of an average week. All these factors are thought to contribute to the phenomenon of social jet lag or circadian misalignment.

Independent of chronotype, sleepiness was also associated with lower self-regulation. In adolescents, sleepiness may be a more accurate indicator than sleep duration of insufficient sleep because it reflects the person’s perception of sleep-related impairment. Sleepiness is probably influenced by factors other than sleep duration that have yet to be elucidated. One of those factors may be chronotype, which we found explained variability in self-regulation, independent of sleepiness or sleep duration. We also found that the negative impacts of increased sleepiness and eveningness chronotype on self-regulation were of similar magnitude regardless of sleep duration. Our findings suggest that clinicians may want to assess daytime sleepiness in adolescents by using existing tools[92,93] and consider whether sleepiness, not just sleep duration, may be a factor in assessing the adequacy of adolescents’ sleep. Researchers should examine the etiology of sleepiness among adolescents, especially among those sleeping ≥8 hours each night, and the

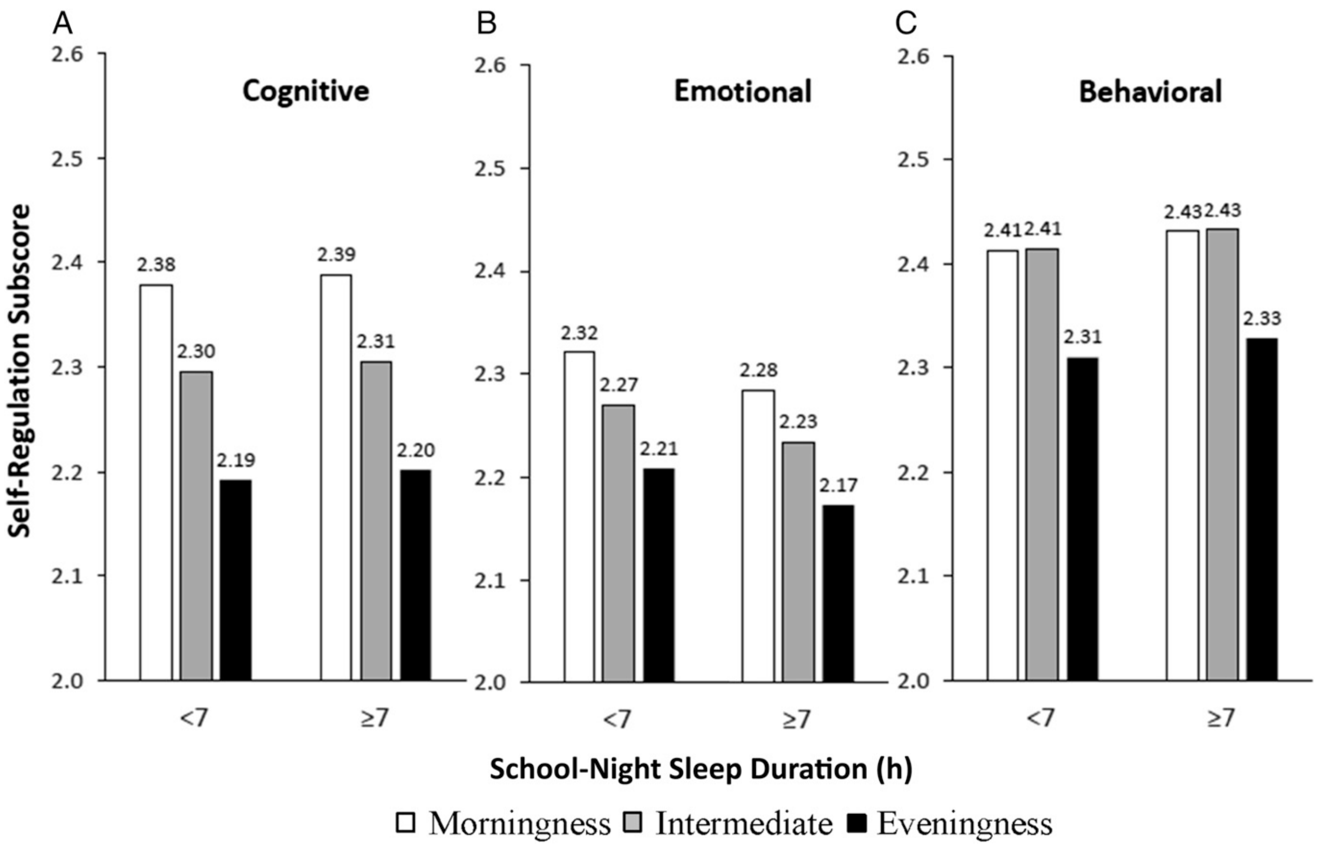

FIGURE 2
Adjusted mean self-regulation subscores by school-night sleep duration and chronotype. Group mean self-regulation subscores are adjusted for sleepiness and 7 covariates (age, sex, race or ethnicity, highest parental education, receipt of free or reduced-price meals, anxiety or mood disorder, and attention-deficit/hyperactivity disorder) and after multiple imputation of missing data ($N = 2017$).

contribution of sleepiness to health and functioning.

Greater self-regulation in childhood is associated with a variety of positive adult outcomes, such as better physical health, more financial security, less criminality, and less substance use,[94] and it is possible that improving early self-regulation may promote health and functioning over the life course. Our data suggest that sleep-related variables contribute to better self-regulation, and future research should prospectively evaluate the impact of multiple dimensions of sleep on the development of self-regulation. Although it is possible that poor self-regulation could contribute to unhealthy sleep practices that in turn result in sleep deficits, reverse causality would not be consistent with experimental studies in children showing that short-term manipulation of sleep alters self-regulation. Our results also have policy implications. For example, both genetic variations in clock genes and environmental influences contribute to the distribution of chronotypes in a given population.[95] Thus, there may be remediable environmental factors that potentially contribute to chronic sleep loss, circadian misalignment, and increased daytime sleepiness in adolescents. In particular, early (before 8:30 AM) school start times, which have been associated with chronic insufficient sleep, increased daytime sleepiness, and social jet lag, especially in eveningness students, may have long-term detrimental effects on adolescent health and functioning.[13,96]

There are limitations to this study. Because of the cross-sectional nature of the design, we cannot infer any causal relationships between variables, nor can we exclude the possibility that poor self-regulation impairs sleep. All our data were self-reported, which may lead to common rater bias. The results related to behavioral self-regulation should be interpreted cautiously because this subscore was derived from 2 items, which may also explain the low internal consistency of the measure. Our sample was not representative of the student population from which it was drawn, and this limitation may reduce the generalizability of the results. However, it is often unnecessary to have representative samples to make valid assessment of the associations between exposures and outcomes.[97]

CONCLUSIONS

Self-regulation in adolescents contributes to a range of positive health and functioning outcomes that have potential long-term implications. The development of self-regulation during adolescence may be adversely affected by exposure to sleep-related stressors, such as the circadian misalignment associated with evening chronotype and increased sleepiness, both of which may be related to the timing and duration of nighttime sleep. Efforts to optimize adolescents' nighttime sleep, including implementation of healthy school start times and education on healthy sleep habits, may mitigate these effects.

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