

# Associations between sleepiness, sleep duration, and academic outcomes in early adolescence

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## Abstract

Insufficient sleep and sleepiness are common in adolescence and can negatively impact school performance. The current study examined sleep duration and sleepiness in academic performance and cognitive processes in early adolescence. Middle school students ( $N = 288$ ;  $M_{\text{age}} = 12.01$ ; 54% female; 48% Black, 37% White, 10% Hispanic) wore activity watches for seven nights, reported on daytime sleepiness, and completed computerized tests of attention and episodic memory. Academic performance was assessed with parent and teacher reports, and math and English/language arts (ELA) grades. Results revealed unique associations between daytime sleepiness and academic outcomes, but not cognitive processes. Both shorter and longer sleep duration were related to fewer academic enablers and lower academic skills and math grades. Students with the highest levels of academic performance occurred near 8 h of sleep per night. These results support the importance of addressing daytime sleepiness and optimal sleep duration in early adolescents.

## KEYWORDS

academic achievement, academic outcomes, sleep, sleepiness

## 1 | INTRODUCTION

Academic achievement in middle school has wide-reaching long-term consequences, with students who perform poorly being less likely to graduate from high school and matriculate to college (Hill & Wang, 2015). Continued academic success contributes to long-term outcomes across the lifespan, such as higher economic earnings and

better mental and physical health (Sass et al., 2016). Low academic achievement in middle school is also linked to poorer psychosocial functioning in high school (Zhang et al., 2019). One important factor related to children's cognitive and academic performance is sleep, which can be measured as sleep duration and related daytime sleepiness (O'hare et al., 2021). However, less is known about the role of sleep in academic skills and enablers, which play a key role in promoting academic success (Farrington et al., 2012). Therefore, the present study examines the roles of sleep duration and daytime sleepiness in a comprehensive set of academic outcomes, including academic skills and enablers, academic achievement, and cognitive processes.

## 1.1 | Academic performance in early adolescence

Early adolescence is a difficult time for many students due to the complexities of transitioning from elementary school to middle school, physical and hormonal changes related to puberty, and increased responsibilities and expectations for socioemotional maturity and independence. These challenges can contribute to decreased academic motivation and lower grades (Goldstein et al., 2015; McGill et al., 2012; Wang & Holcombe, 2010), which then negatively affect academic achievement in high school (Casillas et al., 2012).

Academic achievement is typically measured by grades and test scores, but it is also important to understand specific factors that contribute to learning and academic success (Liu & Hou, 2017; Nisar & Mahmood, 2017). For example, academic skills such as reading comprehension and problem-solving are strongly linked to performance in language-based subjects such as reading, math, and science (DiPerna & Elliott, 2002). Furthermore, attitudes and behaviors such as motivation, engagement, and interpersonal skills also help to foster students' academic success. To this end, DiPerna and Elliott (1999) propose a Model of Academic Competence that describes a set of learning qualities that contribute to academic performance. For instance, *motivation* is important for students' regulation and determination (Jenkins & Demaray, 2015). Effective *study skills* enhance student acquisition and retention of information (Gettinger & Seibert, 2002). Finally, *engagement* and *interpersonal skills* promote active participation and positive interactions with teachers and peers in the classroom (Appleton et al., 2006). These attitudes and behaviors are collectively referred to as academic enablers because they promote students' participation and enable learning in academic settings (DiPerna & Elliott, 2002). In sum, studies that examine academic performance should incorporate a broader set of outcomes that include academic achievement as well as factors related to learning such as academic skills and enablers.

## 1.2 | Cognitive processes

Adolescence is also a dynamic period of cognitive development characterized by developmental increases in processes important for learning and academic achievement (Yurgelun-Todd, 2007). When including measures of cognitive processes in studies, intelligence tests (e.g., Wechsler Intelligence Scale; WISC-V) can provide comprehensive assessment across multiple domains of executive functioning but can carry a heavy time burden related to test administration and scoring, in addition to necessary training required to administer the battery (Wechsler, 2014). Multiple cognitive processes are important for academic success however, attentional and memory abilities in particular play a crucial role in how well students attend to and retain information presented at school. Indeed, attention and memory are strongly associated with school performance. For instance, early adolescents with poor reading skills scored lower on an attention test compared to those with average reading skills (Van Den Boer et al., 2015). Lower scores on an attention task were also linked to lower math achievement in 7–11-year-old students (Antonini et al., 2016). Similarly, students with greater gains in memory skills from childhood to adolescence had higher math achievement (Li & Geary, 2017). Finally, poor readers whose neurocognitive tests revealed memory deficits also had difficulties with reading comprehension (Christopher et al., 2012). Importantly,

tests of memory and attention can be administered in less time than a comprehensive intelligence battery and are easily included in multimethod studies. Taken as a whole, cognitive processes related to memory and attention are fundamental to learning in core academic subjects and should be examined together with academic outcomes.

## 1.3 | Sleep duration

### 1.3.1 | Sleep duration in adolescence

Sleep plays an important role at any age, however, sufficient sleep in adolescence is vital for development. The American Academy of Sleep Medicine recommends 8–10 h of sleep per night for adolescents, yet 40% of US adolescents report getting less than 7 h of sleep on most nights (Paruthi et al., 2016). This insufficient amount of sleep is due in part to adolescents' preference for evening chronicity, which together with early school start times, contributes to shorter sleep duration (Lewin et al., 2017; Twenge et al., 2017) during the week. Moreover, increased academic demands during adolescence negatively impact sleep duration by requiring students to stay awake late at night to complete homework assignments or study for exams (Bauducco et al., 2016; Yeo et al., 2020). Additional contributors to insufficient sleep in adolescents are caffeine use, extracurricular activities, and screen media use (Hisler et al., 2020; Lunsford-Avery et al., 2022; Widome et al., 2019). While changing sleep patterns are fairly normal during puberty, youth that frequently stay awake beyond what many people consider a normal bedtime (delayed sleep phase disorder) may thus experience insomnia or an inability to wake up at a desired time (Micic et al., 2016). Attempts for youth to “catch up” on sleep on weekends by going to sleep later and waking up later (social jet lag), while helpful in obtaining adequate sleep periods, promotes an irregular sleep pattern over time that can be detrimental to physical and mental health. Recent studies have shown that adolescents that have greater mid-sleep differences from school days to weekends are at greater risk for obesity (Cetiner et al., 2021). Importantly, sleep problems related to short sleep duration or irregular sleep patterns can place youth at risk for increased anxiety (Roberts & Duong, 2017) or depression (Orchard et al., 2020), which have been linked to lower academic achievement (Khesht-Masjedi et al., 2019).

### 1.3.2 | Sleep duration and cognitive processes

Although sleep has been recognized as an important contributor to physical health and psychological well-being in adolescence, shorter sleep duration in particular is also detrimental to cognitive processes important for academic success (Fuligni et al., 2018; Ling et al., 2020; Lo et al., 2017; Miller et al., 2021). Indeed, experimental studies showed a significant relationship between short sleep duration and working memory. In one study, adolescents were placed in groups of 9 (no restriction), 6.5, 5, or 5 h with an opportunity of a nap for three nights in a row. Results show that the 6.5 and 5 h groups had significantly lower scores on a test of topographical memory than youth who had no restriction (Cousins et al., 2019). Other studies have provided more specific information about an optimum level of sleep duration. As such, adults who slept 7 or 8 h per night performed better on objective measures of verbal memory and fluency than those who slept less than 6 h or more than 9 h, suggesting that the highest level of memory performance occurs between 7 and 8 h of sleep per night (Kronholm et al., 2009) and also suggests nonlinear relationships exist between sleep duration and cognitive processes. Experimental studies of attention and sleep duration are less common in adolescents but one study in young adult females found that participants in the sleep restriction group (3 h of sleep a night) had lower scores on the Flanker task, a test of selective attention (Cunningham et al., 2018). Alternatively, longer sleep duration has been associated with lower scores on measures of sustained attention and working memory in adolescents, providing additional support that a curvilinear relationship may exist between sleep duration and academic outcomes (Vermeulen et al., 2016). Results

from studies examining sleep duration with memory and attention are important when considering the direct associations of cognitive processes with academic performance in adolescence (Ahmed et al., 2019; Jaekel et al., 2013).

### 1.3.3 | Sleep duration and academic performance

In addition to associations with cognitive processes, cross-sectional and longitudinal studies link shorter sleep duration with lower grades or lower overall grade point average (GPA). For example, first-year college students who reported shorter sleep duration (as measured by the sleep duration submeasure on the Pittsburgh Sleep Quality Index) had lower course grades at the end of their first semester (Baert et al., 2015; Buysse et al., 1989). Comparably, middle school students who reported shorter sleep duration had lower overall high school GPA upon graduation (Asarnow et al., 2014). Like the effects on cognitive processes, longer sleep duration has been associated with poorer academic performance in adolescents, suggesting a curvilinear relationship between sleep duration and academic outcomes. For example, adolescents that reported sleeping an average of 7 and 7.5 h of sleep per night had the highest levels of achievement for English grades and GPA, respectively, compared with youth who reported more or less than these amounts (Fulgini et al., 2018). Although the negative effect of short sleep duration is more salient, commonly due to resulting sleepiness, the mechanism for how longer sleep duration has an impact on grades or GPA is less clear. One plausible explanation links relationships between disrupted or fragmented sleep (i.e., poor sleep quality) and cognitive performance, which in turn is associated with poorer academic outcomes (Antonini et al., 2016; Li & Geary, 2017). Little research has also examined the role of sleep duration in academic skills and enablers that contribute to academic performance. One study of Swiss youth found that those who self-reported less than 8 h of sleep per night had lower behavioral persistence, an important component of motivation (Perkinson-Gloor et al., 2013) also linked to working memory (Abdelrahman, 2020). Furthermore, academic engagement improved in students who increased their sleep duration as a result of later school start times (Meltzer et al., 2019). Another study found that shorter self-reported sleep duration was linked with a lower probability of completing homework in high school students (Widome et al., 2019). Clearly, sleep duration can have a significant impact on academic performance yet more studies are needed that include multiple academic outcomes.

### 1.3.4 | Limitations of sleep duration measures

A major limitation of many studies on sleep duration is the use of self- or parent-reported sleep duration, which is subject to recall bias and typically overestimates sleep time (Schokman et al., 2018). For example, compared with objective sleep measures (i.e., actigraphy), adolescents overestimate their sleep time by over 1 h per night and parents overestimate their children's sleep duration by an average of 90 min (Arora et al., 2013; Breitenstein et al., 2021; Tremaine et al., 2010). Moreover, inaccuracies in self- and parent-reported sleep duration vary across individuals, which attenuates observed relationships between sleep duration and other variables. Thus, more research is needed on the role of objectively measured sleep duration in academic behaviors and outcomes.

## 1.4 | Sleepiness

Youth who experience chronically short sleep duration report feeling sleepy and having difficulties staying awake in class and during other daytime activities (Drake et al., 2003), which can lead to academic problems at school. Indeed, middle school students who report daytime sleepiness receive lower math and reading grades (Liu &

Hou, 2017; Ludwig et al., 2019) and have lower standardized test scores (Philbrook et al., 2018). Daytime sleepiness can also have detrimental impact on cognitive processes important for learning, such as attention. In a study of sleep, attention, and academic achievement in adolescents, results show that greater sleepiness is linked to poorer attention, as measured by the d2 Test of Attention (selective and sustained attention and visual scanning speed) and the Coding subtest (processing speed) of the Wechsler Intelligence Scale for Children (WISC-IV; Perez-Lloret et al., 2013). However, associations between sleepiness and memory are inconsistent across studies. In a study of the effects of sleep restriction in adolescents and young adults, there was no effect of daytime sleepiness on tasks of verbal working memory (Jiang et al., 2011). However, another study demonstrated that greater sleepiness did in fact have a negative effect on episodic memory (Thorley, 2013). It is plausible that only certain aspects of memory are impacted by sleepiness, and this may be further confounded by within person variability (Dirk & Schmiedek, 2016), sociodemographic factors (Engel de Abreu et al., 2014), or test anxiety (Eum & Rice, 2011) making it difficult to determine the unique relationship between sleepiness and cognitive processes. Clearly, further examination of the relationship between daytime sleepiness and cognitive processes is warranted.

Similar to sleep duration, few studies have examined the role of sleepiness in other academic outcomes beyond grades or standardized test scores, such as academic skills and enablers. One study with Finnish students aged 15–20 years revealed that greater sleepiness was related to school burnout, which had a negative impact on motivation (Lehto et al., 2019). Additionally, middle school students with attention deficit hyperactivity disorder (ADHD) who reported greater daytime sleepiness exhibited more homework problems, such as failing to bring home assignments, refusing to do homework, or producing messy or sloppy work (Langberg et al., 2013). Given the established role of daytime sleepiness in academic achievement, it is important to better understand the relationships between sleepiness and factors that contribute to academic performance, such as cognitive functioning and academic skills and enablers.

## 1.5 | Current study

In summary, academic performance in early adolescence is an important determinant of later academic and nonacademic developmental outcomes. Both short and long sleep duration as well as daytime sleepiness have been linked to adolescents' lower academic achievement or cognitive processes, but less is known about their relationships with academic skills and enablers. Further, many studies of sleep and academic outcomes have relied on parent- or self-reports of sleep duration, which are less accurate than objective assessments of sleep. To advance our understanding of the role of sleep in early adolescents' academic functioning, the current study examines relationships between two important sleep dimensions (sleep duration and sleepiness) and multiple aspects of academic functioning (memory and attention, academic skills and enablers, academic grades) using multimethod assessments. It is hypothesized that both shorter and longer sleep duration and greater daytime sleepiness will be associated with lower cognitive processes, academic skills and enablers, and academic performance.

## 2 | METHOD

### 2.1 | Sample

The sample included 288 early adolescents ( $M_{\text{age}} = 12.01$ ; 54% female; 48% Black, 37% White, 10% Hispanic, 5% Other), 262 parents ( $M_{\text{age}} = 40.17$ ; 67% female; 47% Black, 41% White, 9% Hispanic, 3% other), and 40 teachers ( $M_{\text{age}} = 40.30$ ; 80% female; 60% White, 37.5% Black, 2.5% unreported) participating in the Adolescent Diet Study, a 3-year study examining effects of diet and nutrition on emotional functioning and academic performance in middle

school students. Students were recruited from 6th or 7th grade classrooms in 15 schools in the greater Birmingham, AL area. The sample was socioeconomically heterogeneous, with a median annual family income of \$40,001–50,000 and approximately 35% of parents having a college bachelor's or graduate degree. The sample closely mirrored the demographic composition of the Birmingham metropolitan area.

## 2.2 | Procedure

Students were recruited for Wave 1 during regular school days from one homeroom of a teacher that was selected by the principal to serve as the primary contact in each participating school. If there was low interest from the class, a second teacher and corresponding homeroom was selected by the principal. Trained project staff presented information about the study to the students and distributed packets containing information about the study and consent forms. Signed parent consent and student assent forms were collected at school approximately 1 week later (45% participation rate). All data collection activities occurred at school during a regular school week between January and November 2019 before the COVID-19 pandemic. On the first day of the study week, students were provided an activity (ActiGraph GT9X Link) tracker and instructed to wear it on their nondominant hand for 8 consecutive days and 7 nights. During the study week, students also completed a battery of self-report measures via computer-assisted self-interview using electronic tablets during a nonacademic class session. For each student, one primary caregiver (typically, parent) and two teachers of core subjects (i.e., math, English/language arts [ELA], science, or social studies) completed questionnaires online; paper copies were also available. To ensure that teachers knew students well enough to adequately complete study measures, only teachers who taught participating students daily in class were eligible to complete questionnaires. All participants were compensated with gift cards for their time. The University Institutional Review Board approved all study procedures.

## 2.3 | Measures

### 2.3.1 | Episodic memory

Due to the influence of episodic memory on learning and contextual information (Tulving & Donaldson, 1972). Memory was assessed using the Picture Sequence Memory Test (PSMT) from the NIH Toolbox (<http://nihtoolbox.org>; Dikmen et al., 2014). The PMST has shown good convergent validity ( $r = .69$ ) with the Brief Visuospatial Memory Test-Revised and Rey Auditory Verbal Learning Test; Weintraub et al., 2013). For this task, a sequence of color-illustrated pictures appeared one picture at a time for 2.2 s, followed by an audio recording describing the content. After a picture in the sequence was presented, it decreased to a smaller size and moved to a fixed position on the screen. The next picture followed the same process without delay until all pictures were displayed and placed in an arbitrarily ordered sequence. After all the pictures had been presented, they were scattered in a random spatial array in the center of the screen. Students were instructed to move each picture from the center of the screen to its correct location to replicate the previously presented sequence. Students completed two trials with 9 and 15 items, respectively. Scores were based on the number of adjacent pairs of pictures reproduced correctly regardless of the amount of time taken to complete the task. The final score was standardized by age. Higher scores indicate better episodic memory compared with same-age children. Due to significant practice effects, previous studies examining test–retest reliability pooled multiple forms of the test and were determined to be excellent ( $r = .84$ ).

### 2.3.2 | Attention

Attention was assessed using the Flanker Inhibitory Control and Attention Test from the NIH Toolbox (<http://nihtoolbox.org>; Dikmen et al., 2014). Previous studies have determined that the Flanker task has good convergent validity ( $r = .52$ ) with the Delis-Kaplan Executive Function Scales (Delis et al., 2001) and low correlations with the Peabody Picture Vocabulary Test, 4th Edition indicating good discriminate validity ( $r = .06$ ). Further, the Flanker task has shown excellent test–retest reliability in a 2-week test–retest interval after accounting for practice effects ( $r = .85$ ; Zelazo et al., 2014). In the Flanker task, students in the current study viewed a row of arrows and were asked to identify the direction of the center arrow (Zelazo et al., 2013). The score on the task is based on an algorithm that integrates accuracy and reaction time. The final score was age-standardized, with higher scores indicating greater ability to attend to relevant stimuli while inhibiting interference from irrelevant stimuli.

### 2.3.3 | Academic competency and evaluation scales

The Academic Competency and Evaluation Scales (ACES; DiPerna & Elliot, 2002) is a norm-referenced rating scale to assess academic outcomes of students in kindergarten through college. The 32-item ACES short form version was used for the current study (Anthony & DiPerna, 2018). Factor analysis demonstrates a two-factor structure related to academic skills and academic enablers. Within each scale, factor analysis reveals three factors for the Academic Skills subscale (Math, Reading, Critical Thinking) and four factors for the Academic Enablers subscale (Interpersonal Skills, Engagement, Motivation, Study Skills) and have moderate to strong associations with other measures ( $r = .38$  to  $-.87$ ) such as the Iowa Test of Basic Skills (Hoover et al., 1993) and GPAs ( $r = .56$ – $.90$ ; DiPerna & Elliot, 2002). The Academic Skills subscale has recently demonstrated large positive relationships with STAR reading and mathematics scores ( $r = .47$ – $.56$ ) whereas the Academic Enablers subscale yielded small and moderate positive relationships with STAR Reading and Mathematics Scores ( $r = .24$ – $.33$ ). The current study uses subscale averages to demonstrate the range of the response option scores for the sample and allows for scoring with missing items without imputation.

### 2.3.4 | Academic skills

Teachers completed the Academic Skills subscale from the ACES Short Form (Anthony & DiPerna, 2018) for each participating student. This measure includes 14 items related to general academic competencies: Math (four items; e.g., *Using numbers to solve daily problems*), Reading (six items; e.g., *Reading comprehension*), and Critical thinking (four items; e.g., *Drawing conclusions from observations*). Answer choices ranged from 1 (*Far below grade level expectations*) to 5 (*Far above grade level expectations*). Reliability for the Academic Skills subscale demonstrated strong internal consistency ( $\alpha = .98$ ) and had adequate interrater correlations ( $r = .58$ ,  $p < .01$ ) when rated by two academic core teachers (e.g., math, ELA, science, or social studies). Ratings from the two teachers evaluating each child were averaged with higher scores indicating higher academic skills.

### 2.3.5 | Academic enabler

Teachers completed the Academic Enablers Subscale from the ACES Short Form (Anthony & DiPerna, 2018) for each participating student. The measure includes 18 items related to behaviors that enable academic success: Interpersonal skills (five items; e.g., *Interacts appropriately with other students*); Engagement (four items; e.g., *Participates in class discussions*); Motivation (five items; e.g., *Is goal oriented*); and Study Skills (four items; e.g.,

*Completes homework*). These items were rated on a 5-point scale (1 = *Never* to 5 = *Almost always*). All 18 items were averaged, with higher scores indicating more academic enablers. Reliability demonstrated strong internal consistency ( $\alpha = .97$ ) and interrater correlations ( $r = .49, p < .01$ ) were somewhat adequate when rated by two academic core teachers (e.g., math, ELA, science, or social studies). Ratings from the two teachers evaluating each child were averaged with higher scores indicating higher academic enablers.

### 2.3.6 | Homework problems

Parents completed the 20-item Homework Problems Checklist (Anesko et al., 1987), which measures how often their child has problems with homework (e.g., *Fails to bring home assignments and materials*). Items were rated on a scale of 0 (*Never*) to 3 (*Very often*) and averaged with higher scores indicating more homework problems ( $\alpha = .94$ ). The Homework Problems Checklist has been previously normed on 675 students in grades three through six. Factor analysis demonstrated a two-factor structure related to inattention/avoidance of homework and poor productivity/nonadherence (Power et al., 2006) and has demonstrated close associations with other measures of homework such as the Homework Performance Questionnaire ( $r = -.73$ ; Power et al., 2015).

### 2.3.7 | Academic achievement

Math and ELA grades were used as two separate indicators of academic achievement due to the relevance of these academic subjects in federally mandated annual testing in grades 3–8. Final grades were provided by the students' schools at the end of the school year. Grades were calculated as a mean of quarter-term grades during the year in which the student participated in the study. Grades range from 0 to 100, with higher values indicating better performance. It is generally understood that grades of 70 or higher are accepted as "passing."

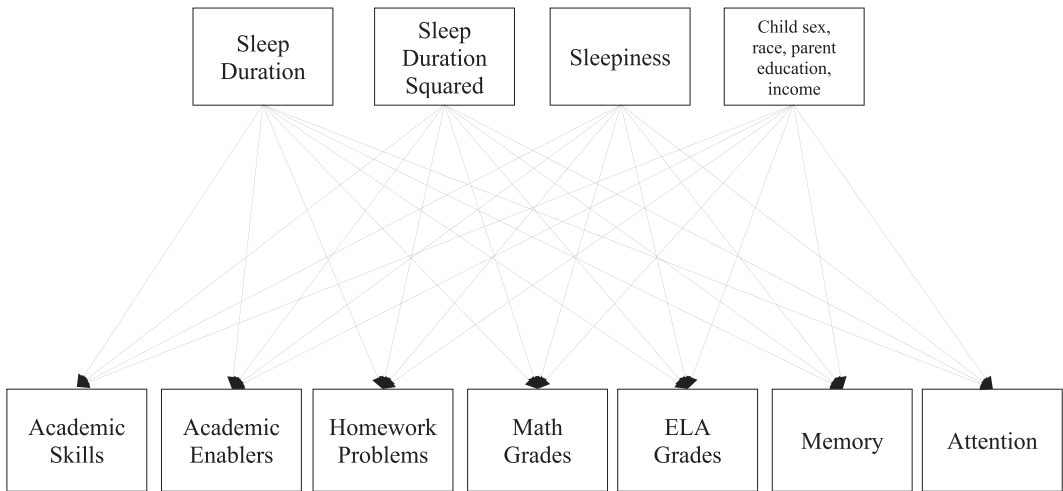
### 2.3.8 | Sleep duration

During the study week, sleep duration was measured with the Actigraph GT9X Link activity tracker the students wore for 7 days and nights and analyzed using Actilife desktop analysis software version 6.13.3. Compared with polysomnography (PSG), often considered the gold standard in evaluating sleep, the use of actigraphy is appealing in research studies due to its low cost and portability. Validated sleep scoring algorithms are then applied to distinguish sleep from wakefulness and calculate sleep duration (Sadeh et al., 2009). Previous studies have found that actigraphy has strong concordance with PSG, despite the limitations of home-based data collection (De Souza et al., 2003). Because adolescents experience more motor activity during sleep, sleep algorithms may underestimate sleep duration (Short et al., 2012). Therefore, sleep duration was computed as the average total time in bed per night across seven consecutive nights.

### 2.3.9 | Sleepiness

Children completed the Pediatric Daytime Sleepiness Scale, an eight-item measure of daytime sleepiness (e.g., *How often do you fall asleep or get drowsy during class periods?*) (Drake et al., 2003) one time during the study week. Answers were rated on a 5-point scale (1 = *Never* to 5 = *Very often/always*). Items were averaged, with higher scores indicating greater daytime sleepiness ( $\alpha = .75$ ).





**FIGURE 1** Multivariate regression path model testing relationships between sleep and academic outcomes. ELA, English/language arts.

### 2.3.10 | Demographic characteristics

Parents reported their child's sex (0 = *male*; 1 = *female*) and race/ethnicity. Race/ethnicity was dichotomized as 0 (*non-Hispanic White*) or 1 (*racial-ethnic minority*). Parents also reported annual household income on a 13-point scale from 1 (<\$5000) to 13 (>\$90,000) and their highest education completed (1 = *Less than 12th grade/no diploma* to 7 = *Graduate or professional degree*).

## 2.4 | Statistical analyses

Descriptive statistics and distributions of all variables were examined. Pearson's correlations tested bivariate associations among sleep variables (sleepiness, sleep duration), academic outcomes (attention, memory, academic skills, academic enablers, homework problems, final math, and ELA grades), and demographics (child sex, race/ethnicity, household income, and parent education). Main analysis included a single multivariate regression path model conducted in Mplus version 8.1. The model included paths from both sleep variables (sleep duration, daytime sleepiness) to each academic outcome (memory, attention, academic skills, academic enablers, homework problems, math, and ELA grades; see Figure 1). To examine curvilinear effects of sleep duration, a quadratic term of centered sleep duration was included as another predictor. Child sex, race/ethnicity, household income, and parental education were included as covariates predicting all academic outcomes. Missing data (6.32% of data points) were handled with Full Information Maximum Likelihood, which utilizes all available data, provides unbiased estimates and standard errors when data are missing at random, and preserves the full sample size ( $N = 288$ ) (Muthén et al., 2017).

## 3 | RESULTS

### 3.1 | Preliminary analyses

Descriptives and bivariate correlations for all variables are presented in Table 1. On average, youth slept just under 8 h per night and reported a medium degree of sleepiness. Compared to a normed average score of 100, youth

TABLE 1 Descriptive statistics and correlations of all variables

	M (SD)	1	2	3	4	5	6	7	8	9	10	11	12
1. Attention	87.24 (12.45)	-											
2. Memory	101.48 (16.55)	0.24**	-										
3. Academic skills	3.13 (2.61)	0.20**	0.19**	-									
4. Academic enablers	3.85 (1.47)	0.05	0.12*	0.76**	-								
5. Homework problems	0.43 (0.48)	0.01	-0.04	-0.35**	-0.36**	-							
6. Math grades	84.69 (10.08)	0.28**	0.27**	0.73**	0.64**	-0.38**	-						
7. ELA grades	85.19 (8.70)	0.27**	0.24**	0.62**	0.56**	-0.33**	0.78**	-					
8. Sleep duration (h/night)	7.84 (0.85)	-0.07	0.04	0.03	0.09	0.07	0.14*	0.19**	-				
9. Sleepiness	2.93 (0.80)	-0.08	-0.12	-0.22**	-0.25**	0.12*	-0.29**	-0.30**	-0.17**	-			
10. Female <sup>a</sup>	54%	-0.07	-0.07	0.14*	0.30**	-0.24**	0.16*	0.23**	-0.01	0.01	-		
11. Racial-ethnic minority <sup>a</sup>	63%	-0.23**	-0.12*	-0.23**	-0.20**	-0.14**	-0.36**	-0.41**	-0.15*	0.05	0.15	-	
12. Household income	8.41 (4.06)	0.21**	0.15*	0.32**	0.27**	-0.01	0.34**	0.39**	0.05	-0.12	0.00	-0.39**	-
13. Parent education	4.10 (2.02)	0.16*	0.03	0.26**	0.18**	-0.02	0.30**	0.31**	0.12	-0.11	0.11	-0.26**	0.49**

Abbreviation: ELA, English/language arts.

<sup>a</sup>Point biserial correlations;\* $p < .05$ ; \*\* $p < .01$ .

performed right at average on attention yet somewhat lower on memory. Average math and ELA grades fell in the middle of the B range. Teachers reported that on average students had academic skills slightly above grade expectations and engaged in academic enablers sometimes too often. Parents reported low levels of homework problems. Correlations determined that longer sleep duration was related to less daytime sleepiness and higher math and ELA grades. Sleepiness was associated with lower academic skills and enablers, more homework problems, and lower math and ELA grades. As expected, memory and attention scores were positively correlated with each other and with academic skills and grades. All academic outcomes were moderately to highly correlated. Among the covariates, better academic outcomes were associated with female sex, higher household income and parental education, and not being a racial-ethnic minority.

### 3.2 | Multivariate regression analyses

Descriptives and bivariate correlations for all variables are presented in Table 1. Results from the multivariate regression path model indicated that after adjusting for demographic covariates, longer sleep duration was linked to lower academic skills. Sleep duration was not uniquely related to any of the other academic outcomes, but the quadratic effect of sleep duration was significant for academic skills, academic enablers, and math grades. Specifically, both shorter and longer sleep duration were associated with lower academic skills, fewer academic enablers, and lower math grades (Figures 2–4). As shown in the figures, the highest levels of academic functioning occurred near 8 h of sleep per night. Further, greater daytime sleepiness was associated with lower academic skills, fewer academic enablers, more homework problems, and lower math and ELA grades (Table 2). Daytime sleepiness was not uniquely related to attention and memory.

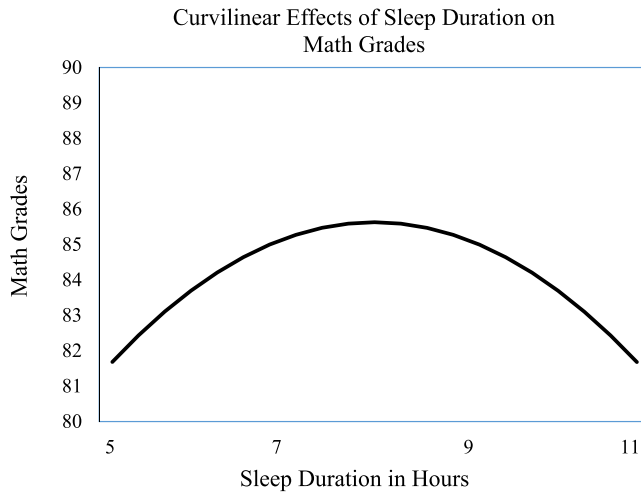
Regarding demographic covariates, females had higher academic skills, more academic enablers, fewer homework problems, and higher math and ELA grades than males. Racial-ethnic minority students had lower scores on the attention task, more homework problems, and lower math and ELA grades compared with non-Hispanic white students. Higher household income was linked to higher academic skills, academic enablers, and ELA grades. Finally, parental education was related to higher math and ELA grades.

## 4 | DISCUSSION

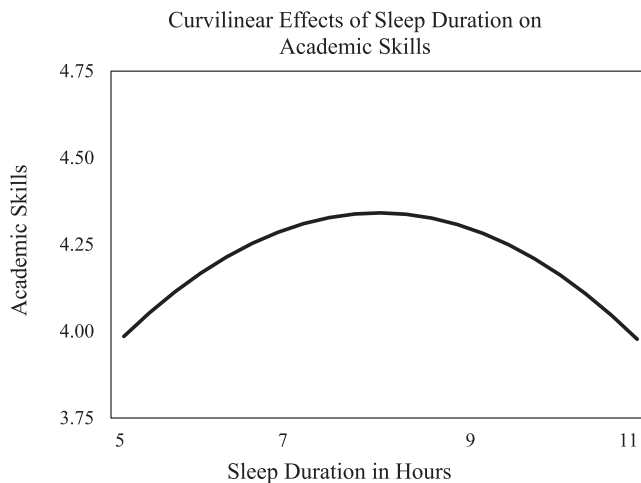
This study utilized multisource measurements to examine the roles of daytime sleepiness and sleep duration in multiple academic outcomes in early adolescents. After adjusting for sociodemographic characteristics, results showed longer sleep duration was linked to poorer academic skills. Additionally, both shorter and longer sleep duration were related to lower academic skills, fewer academic enablers, and lower math grades. There were unique associations between daytime sleepiness and lower academic skills and enablers, more homework problems, and lower math and ELA grades. Contrary to expectations, neither sleep duration nor sleepiness were related to attention and memory performance.

### 4.1 | Sleep duration and academic outcomes

This study was the first to determine that longer sleep duration was associated with poorer academic skills, consistent with other studies linking too much sleep with lower well-being. For example, one study showed that young adolescents reporting too much sleep were also reported more unhappiness, thoughts of suicide, and other mood disturbances (Roberts et al., 2001). At least one study of adolescents found no effect of sleep duration (Adelantado-Renau et al., 2019). However, the present results also show that testing the simple linear effect of



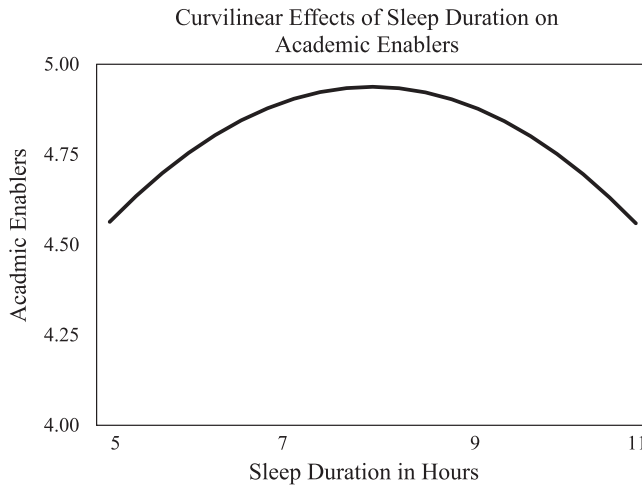
**FIGURE 2** Longer and shorter sleep duration is associated with lower math grades.



**FIGURE 3** Longer and shorter sleep duration is associated with lower academic skills.

sleep duration on adolescents' functioning is not optimal, given the presence of nonlinear relationships between sleep duration and several outcomes.

Specifically, both shorter and longer sleep duration was associated with poorer academic skills, academic enablers, and math grades in this study. These findings are consistent with several other investigations that linked short and long sleep duration with poorer academic outcomes (Faught et al., 2017; Unalan et al., 2013). Although few studies tested the curvilinear effect of sleep duration explicitly, one other study found this same quadratic effect of sleep duration for standardized test of problem-solving in elementary school children (Eide & Showalter, 2012). Together, these results suggest that both short and long sleep duration may have a negative impact on multiple aspects of children's academic functioning, including academic enablers, skills, and grades. Short sleep duration has been consistently linked to decreased cognitive processes and poorer academic outcomes (Baert et al., 2015; Fuligni et al., 2018) which is likely due to negative effects of sleepiness. However, factors that help explain the detrimental effect related to long sleep duration are less clear. One plausible explanation may be the



**FIGURE 4** Longer and shorter sleep duration is associated with fewer academic enablers.

result of sleep disorders such as obstructive sleep apnea which have shown previous associations with poor academic performance (Goyal et al., 2018) and may facilitate longer sleep duration due to poor sleep quality. Future studies should examine the mediating role of sleep disorders and sleep quality in relationships between longer sleep duration and academic outcomes. Another potential reason may occur because of sleep inertia, a transition state between sleep and wake which includes a desire to return to sleep. This could potentially have implications for adolescents, who have reported in previous studies that they have difficulty awakening (Amaral et al., 2014) and thus more likely to sleep longer. It is important to note that possible role of psychosocial factors in relationships between sleep and academic outcomes. Due to increased internalizing that many youth experience during adolescence (Hankin et al., 2015), depression or anxiety may play an interactive role in the relationship between sleep duration and academic functioning due to the strong relationship that internalizing has with both sleep quality and academic performance (Short et al., 2013). Therefore, measures that assess these constructs should be incorporated into future studies to determine moderating effects of psychosocial functioning in the relationship between sleep duration and academic outcomes in young adolescents. Interestingly, in the present study academic functioning peaked at about 8 h of sleep, which is consistent with current recommendations of 7–9 h of sleep per night for adolescents (Paruthi et al., 2016).

## 4.2 | Daytime sleepiness and academic outcomes

The robust associations observed between daytime sleepiness and a broad range of academic outcomes are consistent with other studies demonstrating lower grades and test scores among students who report greater daytime sleepiness (Liu & Hou, 2017; Ludwig et al., 2019; Philbrook et al., 2018). Importantly, this was the first study to extend the effects of sleepiness to academic skills and enablers, key contributors to academic achievement (DiPerna & Elliott, 2002). Previous research in adults has linked daytime sleepiness with lower motivation and interpersonal skills, specific components of academic enablers (Appleton et al., 2006). In one experimental study, adults who were reported sleepiness after being forced to stay awake all night were less motivated to participate in social and physical activities the next day compared with adults who received 7–9 h of sleep (Axelsson et al., 2020). In another study of children with ADHD, daytime sleepiness was related to more behavioral problems (Lucas et al., 2019). Together, these two studies suggest that feeling sleepy may have a negative impact of

TABLE 2 Standardized estimates from a multivariate regression path model predicting academic outcomes from sleep and demographic variables

	Attention, $\beta$ (SE)	Memory, $\beta$ (SE)	Academic skills, $\beta$ (SE)	Academic enablers, $\beta$ (SE)	Homework problems, $\beta$ (SE)	Math final grades, $\beta$ (SE)	ELA final grades, $\beta$ (SE)
Sleep duration	-.13 (0.07)	.02 (0.07)	-.16 (0.08)*	-.11 (0.06)	.09 (0.10)	-.07 (0.06)	.01 (0.05)
Sleep duration quadratic term	-.02 (0.06)	-.07 (0.05)	-.17 (0.09)*	-.18 (0.07)**	-.05 (0.09)	-.14 (0.06)*	-.07 (0.04)
Sleepiness	-.01 (0.07)	-.09 (0.07)	-.18 (0.06)*	-.21 (0.06)**	.16 (0.06)**	-.22 (0.06)**	-.21 (0.06)**
Female	-.04 (0.07)	-.10 (0.07)	.15 (0.06)*	.37 (0.05)**	-.26 (0.06)**	.13 (0.06)*	.24 (0.05)**
Racial-ethnic minority	-.17 (0.07)*	-.05 (0.07)	-.10 (0.07)	-.05 (0.06)	-.17 (0.07)*	-.18 (0.07)**	-.25 (0.07)**
Household income	.10 (0.07)	.13 (0.07)	.21 (0.08)*	.14 (0.07)*	-.12 (0.08)	.12 (0.08)	.16 (0.08)*
Parent education	.12 (0.07)	-.04 (0.07)	.10 (0.07)	.09 (0.06)	-.06 (0.06)	.17 (0.06)**	.15 (0.07)*

Note:  $N = 288$ .

\* $p < .05$ ; \*\* $p < .01$ .

students' motivation to complete classwork and homework assignments, as well as on interpersonal skills important for engaging appropriately with peers at school. In turn, reduced academic motivation and appropriate interpersonal engagement, important components of academic enablers, may be detrimental to the development of academic skills, learning, and achievement.

Thus, interventions targeting children's sleep may help improve academic functioning. Unfortunately, interventions that address sleep duration, the primary cause of sleepiness, have not consistently reduced daytime sleepiness (Åslund et al., 2018). Directly addressing daytime sleepiness may yield more effective results as found in one intervention study of sleep quality and sleepiness. Older adults who participated in a home exercise and sleep hygiene program reported better quality sleep and a decline in daytime sleepiness (Brandão et al., 2018). There are fewer studies in adolescents however, one study found that children who participated in classroom activities (e.g., role-playing, games, personal goal setting) focused on the benefits of good sleep hygiene went to bed earlier on school and weekend nights and had better self-reported sleep hygiene (Wolfson et al., 2015). Regarding daytime sleepiness, Isa and colleagues investigated the prevalence of daytime sleepiness and the association of physical activity among children aged 9–12 (Isa et al., 2019). Results showed that older students had higher levels of daytime sleepiness. Further, multiple logistic regression analysis demonstrated that lower physical activity was significantly associated with daytime sleepiness after adjusting for multiple cofounders. Experimental studies in adults have shown that short naps were found to reduce drowsiness in night shift workers, but this has not been tested in children (Geiger-Brown et al., 2016). Together, these results suggest that physical activity and napping may help improve academic outcomes for students who struggle with daytime sleepiness, however, more research using adolescents is needed to determine if napping could also be detrimental to sleep timing and duration.

### 4.3 | Sleep, attention, and memory

Results from this study found that neither sleep duration nor sleepiness was related to attention or memory. This is contradictory to evidence supporting associations between short sleep duration and poorer cognitive processes (Cousins et al., 2019; Fuligni et al., 2018). Likewise, the present results were inconsistent with previously reported associations between sleepiness and poorer memory in children (Perez-Lloret et al., 2013). One plausible reason may be due to the use of only one facet of memory or attention and may require multiple assessments within each domain. However, the present findings are similar to one review that determined that the relationship between sleep duration and cognitive processes was inconsistent across cognitive domains, including no relationships of sleep duration with attention or memory (Short et al., 2018). However, other domains of cognitive processes, such as reasoning and verbal ability, have been found to be affected by shorter sleep duration (Wild et al., 2018). Importantly, even if sleep duration does not affect attention and memory, as suggested by the present study, other domains of cognition may be affected by sleep, which in turn can have a negative impact on academic outcomes (Gómez-Veiga et al., 2018). It will be important for future studies to examine the effects of sleep duration and sleepiness on a broader set of cognitive domains.

### 4.4 | Implications

The present results point to the importance of explicitly testing nonlinear effects of sleep duration in future research, as both short and long sleep duration were associated with lower levels of academic functioning. Moreover, the results support the need for more research on the role of sleep in a broad range of academic behaviors that contribute to academic performance, such as academic enablers and homework activities. Better understanding of how specific dimensions of sleep affect these proximal academic processes may be helpful in designing interventions and testing their effectiveness in real-time to guide modifications as needed, rather than

relying on more distal academic outcomes such as final grades. Future studies should also consider demographic characteristics to examine how various subgroups of youth may differ in the role sleep plays in academic performance. These findings also have practical implications for teachers, counselors, and administrators in school settings. For example, in a study of high school students, a 55 min delay in school start time (8:45 a.m. vs. 7:50 a.m.) resulted in approximately a 30 min increase in students' sleep duration on school nights. Further, students reported decreased sleepiness, higher grades, and better attendance (Dunster et al., 2018) which has a positive impact on overall child well-being. Results from the present study provide further support for later school start times to allow more sleep, reduce sleepiness, and improve academic outcomes in adolescents. Also, evidence supports the important role that physical activity may play in improving sleep and reducing daytime sleepiness (Isa et al., 2019; Master et al., 2019). As such, school administrators should support physical education programs in their schools. Further, programs and policies that encourage teachers to initiate short bouts of physical activity during the school day may be helpful. Similarly, schools should educate staff about how to screen for clinical sleep disorders and depression, especially for youth who are not meeting academic expectations. Finally, interventions that increase awareness about the connections between sleep, sleep hygiene, and positive academic achievement may be beneficial to help youth and their families strive for the optimal amount of sleep and reduction of sleepiness. Because sleep behaviors are modifiable, interventions targeting improved sleep in early adolescence may decrease sleepiness and have a positive impact on academic enablers, skills, and performance, with long-term implications for youth's academic and nonacademic outcomes.

## 4.5 | Limitations

The results of this study need to be interpreted in the context of several limitations. First, the cross-sectional design limits inferences about the directionality of the obtained effects. It is possible that academic functioning or related variables affect sleep duration and sleepiness. Longitudinal and experimental studies are needed to support directional or causal interpretations of the relationships between sleep and academic functioning. Next, the participants were recruited from mostly public schools in a large metropolitan area in the Southeast United States, so results may not generalize to other geographic regions, ethnicities, or cultures. The study included multiple informants and sources of data, but youth self-report of sleepiness may still be subject to recall bias. The current study assessed only two domains of cognitive processes, but other dimensions of cognition may have provided a more comprehensive understanding of the effects of sleep duration and sleepiness. Although the Flanker task has previously indicated strong validity and reliability, at least one study determined that several interference tasks are not associated with self-reported measures of self-control or impulsivity (Paap et al., 2020). This further supports the need for incorporating multiple measures of cognitive processes in future examinations of sleep behaviors. Also, symptoms of clinical sleep disorders (e.g., apnea, insomnia) and other variables related to adolescent sleep (e.g., technology use) were not assessed, but may have impacted sleep duration and sleepiness, as well as academic performance. The study may also have been limited by obtaining only 1 week of sleep duration, which may not be an adequate amount of time to detect an effect on academic achievement. Further, the current study did not assess sleep latency (falling asleep) or other sleep periods, such as daytime napping, which could influence sleep timing and thus duration. Although inclusion criteria stated that students speak English and are able to mentally and physically complete study tasks, information regarding student's involvement in any academic accommodations or services was not obtained. Finally, as with many aspects of adolescent development, there are likely multiple factors that play a moderating role in relationships between sleep duration and academic outcomes (e.g., emotion regulation) that warrant greater examination. Future studies should also incorporate clinical sleep problems and other factors related to adolescents' sleep within a longitudinal or experimental design to better understand the relationships between sleep and academic performance.



## 5 | CONCLUSION

This study used multisource measures to provide a comprehensive evaluation of the roles of sleep duration and sleepiness in a broad range of academic outcomes in an ethnically and socioeconomically diverse sample of early adolescents. The results provide compelling evidence linking daytime sleepiness with difficulties in multiple types of behaviors that support academic achievement, including academic skills and enablers, homework completion, and grades. More research is needed to examine reasons for daytime sleepiness and the specific mechanisms through which daytime sleepiness affects academic outcomes. Furthermore, the results suggest that both short and long duration of sleep contribute to fewer academic enablers and lower academic skills and math grades. Future studies should continue to examine the roles of both short and long sleep duration in cognitive processes and academic outcomes.

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### DATA AVAILABILITY STATEMENT

Research data are not shared.

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