Sleep Duration and Kindergarten Adjustment

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abstract

OBJECTIVES: The current study examined longitudinal linkages between child sleep duration and children's socioemotional, learning engagement, executive functioning, and academic outcomes across the full kindergarten (K) year.

METHODS: A measurement-burst design was employed to examine 3 different measures of child sleep duration in 7-day bursts at pre-K (July–August), early K (late September), mid-K (late November), and late K (mid-to-late April), using wrist actigraphy. These measures included mean amounts of child sleep per 24-hour period across the full week, proportion of 24-hour periods per week that children slept 10 or more hours, and proportion of nighttime sleep periods per week that children slept 10 or more hours. Children's outcomes at early, mid-, and late K were provided by their K teachers blind to children's sleep histories, and by assessments administered by project staff.

RESULTS: Among the 3 sleep measures examined, regularity of nighttime sleep in which children slept 10 or more hours per night, especially at pre-K, consistently predicted more favorable K outcomes in both socioemotional, learning engagement, and academic domains. Results suggested that establishing healthy nighttime sleep habits before K start was especially promotive of better K adjustment across the full K year. These findings were controlled for income-to-poverty threshold ratios, child health status, and number of missed school days.

CONCLUSIONS: Efforts to promote a favorable transition to first-time schooling should pay particular attention to sleep hygiene and regularity of 10-plus hours of nightly child sleep established before the start of K.

WHAT'S KNOWN ON THE SUBJECT: Sleep and children's functioning has been linked to school success among older children, although most previous work is cross-sectional. Little is known of longitudinal linkages between sleep duration and children's adjustment when transitioning to kindergarten and across the school year.

WHAT THIS STUDY ADDS: The current study is the first to examine the role of child sleep duration, objectively assessed across the full kindergarten year, in predicting children's cognitive, academic, and socioemotional adjustment across this same time, net of socioeconomic and child health factors.

To cite: Teti DM, Whitesell CJ, Mogle JA, et al. Sleep Duration and Kindergarten Adjustment. *Pediatrics*. 2022;150(2):e2021054362

The transition to kindergarten (K) requires new social, emotional, and cognitive competencies, significant expansion of children's social networks, and formal instruction and evaluation never experienced before.[1,2] Children's adjustment to K has multiple determinants, with contributions from socioeconomic status,[2] child health,[3] attendance history,[4] and other factors. Curiously, 1 determinant largely missing in studies of K transition is children's sleep duration. This is noteworthy, given that sleep disturbances in young children are common (prevalence rates between 20% and 30%[5–7]) and that sleep deficiencies in childhood are predictive of compromised functioning in cognitive,[8] behavioral,[9] emotional,[9] and academic domains.[10]

To date, few studies have examined links between sleep duration and school adjustment at K age. Ravid et al,[11,12] found that 5-to-6-year-olds with sleep problems, including shorter sleep duration, scored significantly lower on achievement tests at the end of first grade than children without sleep disturbances. Liu et al[8] found that Chinese children who had difficulties settling to sleep and staying asleep (from parent reports on the Chinese version of the Child Behavior Checklist) scored lower on standardized IQ tests than children without sleep problems. As yet, however, no studies have evaluated the impact of sleep duration on children's adjustment to K across the full year.

THE CURRENT STUDY

The current study's measurement-burst design embedded 4 bursts (8 consecutive days) of sleep measurement and child outcomes across the K year. We took into consideration child sleep guidelines from the American Academy of Sleep Medicine (AASM)[13] and the National Sleep Foundation,[14] which recommend 10 to 13 hours of sleep

per 24 hours for children at 5 years. We examined 3 separate predictors of children's K adjustment:

1. mean levels of child sleep per 24 hours;
2. proportion of 24-hour periods across the week in which children had at least 10 or more hours of sleep; and
3. the proportion of nighttime sleep periods only across the week in which children slept 10 hours or more.

We hypothesized that children obtaining more sleep would show higher levels of socioemotional and learning engagement, executive functioning, and academic outcomes, net of socioeconomic, health, and school attendance covariates, compared with children with lesser amounts of sleep. Central to the current study was to examine how well this prediction held across the 3 sleep predictors.

METHODS

Participants, Study Design, and Procedures

This study was approved by the internal review board of the Office of Research Protections at Pennsylvania State University. Families were initially approached during the February to May K registration at 3 school districts in a mid-size county in southeastern Pennsylvania from April 2016 to May of 2019. Two-hundred thirty families (out of 1158 expressing interest) were recruited, and all except 10 children were in full-day K. Inclusion/exclusion criteria were that parents were aged 18 years or older, conversant in English, and living with their child(ren).

Recruitment of families was stratified by child biological sex and severity of child sleep issues within each school district from parent-report at K

registration. Parents provided information on a 0-to-2 scale on bedtime resistance, latency between bedtime and sleep onset, difficult waking in the morning, night waking frequency, and bedtimes after 9 PM. Scores on this 0-to-10 composite were stratified to create a minimally skewed sample with a wide range of sleep problems at study onset (mean = 4.45, SD = 2.52, skewness = 0.14). Efforts were also made to randomly oversample racial and ethnic minority families to meet a National Institutes of Health-recommended recruitment goal of 20% to 25% racial and ethnic minority families. Oversampling led to 23.1% racial/ethnic minority families in the final sample.

Informed consent with parents was acquired in-home at the start of the summer pre-K visit. Families were visited at home at the following times: July to August, September, November, and April/May of the K school year.

Sixty-four teachers provided assessment information on the children at early-, mid-, and late-K. Informed consent of teachers was acquired at their schools before the start of K. Number of classrooms per district ranged from 7 to 22 and varied each year depending on the size of the incoming K class. Number of K classrooms with study participants also varied across data collection: year 1 = 19, year 2 = 43, year 3 = 38, year 4 = 22. Each teacher rated 1-to-5 students per year.

MEASURES

Child Sleep Duration

Children were provided with a Spectrum Plus Actiwatch (Philips Healthcare, Murrysville, PA), worn on the wrists beginning on Saturday and continuing for the next 8 consecutive days at all assessment points. The validity and reliability of

TABLE 1 Sample Demographics (N = 221)

Target Child Characteristics, % (N)	
Race	
White	76.9 (170)
African American	7.7 (17)
Asian American	0.9 (2)
American Indian	0.5 (1)
2 or more races	12.2 (27)
Another race	1.8 (4)
Hispanic	8.6 (19)
Child gender, female	50.7 (112)
School district % (N)	
District 1	39.8 (88)
District 2	26.2 (58)
District 3	33.9 (75)
Caregivers in home % (N)	
Living with partner	
2 parents participating	76.0 (168)
Mother only participating	17.2 (38)
Mother and grandparent participating	0.0 (0)
Not living with partner	
2 parents participating	0.0 (0)
Mother only participating	5.4 (12)
Mother and grandparent participating	1.4 (3)
Mother % (N)	
Less than high school diploma	1.8 (4)
High school diploma/GED	29.8 (65)
Associate's degree	15.6 (34)
Bachelor's degree	27.1 (59)
Master's degree	19.7 (43)
Doctoral or Law degree	6.0 (13)
Father, % (N)	
Less than high school diploma	2.4 (4)
High school diploma/GED	37.2 (61)
Associate's degree	15.2 (25)
Bachelor's degree	28.7 (47)
Master's degree	12.2 (20)
Doctoral or Law degree	4.3 (7)
Mother age	
Mean (SD)	34.62 (4.95)
Range	23–55
Father age	
Mean (SD)	36.95 (6.28)
Range	23–67
Household	
Mean (SD)	
Adults in home	2.02 (0.41)
Children in home	2.31 (0.92)
Total people in home	4.35 (1.03)
Income	$83 400 ($31 000)
Relation to the poverty line	382% (155%)
Range	
Adults in home	1–4
Children in home	1–5
Total people in home	2–8
Income	≤$10 000–>$200 000
Relation to the poverty line	At/below to 500% above

these devices have been demonstrated in both children and adults.[15,16] The Sadeh algorithm[17] was used to determine sleep onset and offset.

The devices sampled activity at the medium sensitivity threshold across 30-second intervals and were equipped with off-wrist detection.

Any nights during which the watch was off-wrist for >60 minutes were excluded from analysis. At all time points, the average number of scorable days was between 6 and 7. Daytime rest periods of 20 minutes or more were scored as daytime sleep. Parent-completed daily diaries were used to cross-check Actiwatch data for sleep onsets and wake-ups. Actiwatch and diary data converged +/− 18 minutes, on average, >90% of the time.

Actigraph data were used to derive the 3 child sleep predictor measures at each measurement occasions:

1. mean levels of sleep per 24 hours, averaged across the full week of data collection;
2. proportion of 24-hour periods per week that each child slept 10 or more hours; and
3. proportion of nighttime sleep periods per week in which each child slept 10 or more hours.

Kindergarten Outcomes

Children's K outcomes were obtained from teacher-report and trained observers at all assessment points, using well-validated measures. With 1 exception (the Attention-Deficit/Hyperactivity Disorder [ADHD] Rating Scale), higher scores indicated better performance.

Socioemotional and Learning Engagement Measures

Teachers completed the 7-item Teacher Observation of Classroom Adaptation, Revised,[18] to assess aggression, and the 11-item Social Competence Scale[19] to assess prosocial behaviors, internalizing behaviors, and emotion regulation. Teachers completed the 28-item Student–Teacher Relationship Scale[20] to assess student–teacher closeness and conflict, and the 29-item Learning Behaviors Scale[21] to assess academic task orientation along dimensions of learning

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TABLE 2 Multilevel Modeling Results Examining the Impact of Mean Duration of Child Sleep Per 24-Hour Period on Child Outcomes in Kindergarten, Socioemotional and Learning Engagement Measures

	Socioemotional Measures			Learning Engagement Measures			
	Social Competence (SCS)	Aggression (TOCA-R)	Student–Teacher Relationship (STRS)	Learning Behaviors (LBS)	School Readiness (SRQ)	ADHD Symptoms	Task Orientation (TOS)
Intercept	39.06* (10.91)	33.17* (4.87)	131.47* (12.87)	60.12* (9.70)	93.39* (14.80)	6.96 (9.32)	16.12* (4.34)
Time	−1.79 (6.97)	−1.34 (3.11)	−7.65 (8.24)	−7.78 (6.22)	−25.72** (9.51)	10.96 (5.97)	1.15 (2.78)
WP sleep	−0.01 (0.02)	−0.00 (0.01)	−0.03 (0.02)	−0.03 (0.02)	−0.06*** (0.02)	0.01 (0.02)	−0.01 (0.01)
WP sleep × time	0.00 (0.01)	0.00 (0.01)	0.01 (0.01)	0.01 (0.01)	0.04** (0.02)	−0.02 (0.01)	0.00 (0.01)
Pre-K sleep	0.03 (0.02)	0.01 (0.01)	0.03 (0.03)	0.03 (0.02)	0.05 (0.03)	−0.03 (0.02)	0.02*** (0.01)
Pre-K sleep × time	−0.01 (0.01)	−0.00 (0.00)	0.01 (0.01)	−0.01 (0.01)	−0.02 (0.01)	0.02 (0.01)	0.00 (0.00)
BP sleep	0.04 (0.03)	0 0.01 (0.01)	0.07 (0.04)	0.04 (0.03)	0.06 (0.04)	−0.02 (0.03)	0.01 (0.01)
Covariates							
Poverty line	1.16*** (0.37)	0.34 (0.17)	0.92 (0.47)	1.13** (0.33)	1.94* (0.46)	−0.90*** (0.37)	0.26*** (0.12)
Child health	0.12 (0.08)	0.04 (0.04)	0.18 (0.10)	0.15*** (0.07)	0.13 (0.10)	−0.09 (0.08)	0.02 (0.03)
Cohort	0.30 (0.67)	−0.30 (0.31)	0.67 (0.85)	0.59 (0.58)	0.66 (0.79)	−0.64 (0.64)	0.42*** (0.20)
Missed school days							
WP	1.70*** (0.71)	0.75*** (0.32)	1.41 (0.84)	−0.16 (0.64)	0.54 (0.98)	−0.04 (0.61)	−0.56 (0.31)
BP	−0.15 (1.66)	0.07 (0.80)	−0.19 (2.11)	−1.56 (1.47)	−2.16 (2.06)	0.50 (1.65)	−0.96 (0.56)

Note: numbers in parentheses are SEs. Time = time of assessment across the K year: pre-K (July–August), early K (September), mid-K (November), late K (April). Sleep = mean sleep duration per 24-hour period at each assessment point; sleep × time = interaction of sleep by time. Pre-K sleep = between-person sleep at pre-K only; pre-K sleep × time = interaction of pre-K sleep by time. WP deviations from one's cross-time average; between-person sleep averaged across all time points. * $P < .001$, ** $P < .01$, *** $P < .05$. BP, between person; LBS, Learning Behaviors Scale; SCS, Social Competence Scale; STRS, Student–Teacher Relationship Scale; TOCA-R, Teacher Observation of Classroom Adaptation, Revised.

enthusiasm, task persistence, and frustration tolerance. Teachers completed the 14-item School Readiness Questionnaire (SRQ),[22] assessing self-regulation, compliance, and learning motivation, and the 14-item ADHD Rating Scale.[23] During school visits, project staff completed the 6-item Task Orientation Scale (TOS),[24] assessing child engagement, persistence, attention to detail, and desire to do well on 4-point scales.

Executive Functioning

At each school visit, project staff conducted the forward digit span task, a working memory assessment from the Wechsler Intelligence Scales for Children, Third Edition,[25] and the Connors' Kiddie Continuous Performance Test (KCPT-2),[26] a standardized assessment for clinically significant attention problems.

Academic Outcomes

For each child, teachers completed the 19-item Academic Performance Rating Scale (APRS),[27] assessing quantity and quality of work, general organization, and attention to classwork, and the reading/language arts, mathematics, and critical thinking subscales of the Academic Competence Evaluation Scales.[28] During school visits, project staff completed a subtest of the Dynamic Indicators of Basic Early Literacy Skills (DIBELS), Sixth Edition,[29] which assessed ability to recognize upper-case and lower-case letters within 60 seconds, and 2 subtests of the Test of Word Reading Efficiency[30] to test children's recognition of short sight words and ability to sound out nonwords.

Data Analysis

Multilevel linear models addressed primary research questions. Because some children were rated by the same teacher, we included a level for nesting to account for this shared variance (level 3). At level 1, all models included primary sleep predictors at each time point and a sleep by time interaction. Level 2 included average sleep across time, sleep at pre-K, and the cross-level interaction between pre-K sleep and time. Number of missed school days was included as a covariate at level 1, whereas household income relative to the federal poverty line,[31] mothers' reports of overall child health,[32] cohort (the K year in which data were collected), and missed school days were included as covariates at level 2. All models included random intercepts, and all level 2 variables were grand mean-centered. Criterion α for all analyses was $P \leq .05$, and all estimates are reported in unstandardized units. Effect sizes were calculated using Cohen's d or the φ coefficient.

RESULTS

Of the 230 families recruited, 221 completed the full study. Power analyses conducted for a sample size of 225, 5% attrition rate, and models with 8 or more predictors, yielded power coefficients of >0.80 to detect significant effects with small effect sizes.

The majority of children in the study sample were White (76.9%), with the remaining children African American, Asian American, >1 race, or "other". A small percentage of

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TABLE 3 Multilevel Modeling Results Examining the Impact of Mean Duration of Child Sleep Per 24-Hour Period on Child Outcomes in Kindergarten, Executive Functioning and Academic Measures

| | Executive Functioning Measures | | Academic Measures | | | | |
| | Working Memory (WISC III) | Attentional Functioning (KCPT-2) | Academic Performance (APRS) | Academic Competence (ACES) | Letter Recognition (DIBELS) | TOWRE | |
						Site Word Efficiency	Phonemic Decoding
Intercept	6.35* (1.93)	−1.13 (1.73)	78.18** (10.12)	103.97** (28.84)	−23.34 (18.57)	−15.16 (18.97)	7.94 (17.84)
Time	1.46 (1.22)	1.16 (1.04)	−1.48 (6.47)	−23.85 (16.79)	30.44*** (11.84)	24.54*** (11.39)	3.94 (10.71)
WP sleep	−0.00 (0.00)	−0.00 (0.00)	−0.02 (0.02)	−0.05 (0.05)	0.07*** (0.03)	0.02 (0.03)	−0.01 (0.03)
WP sleep × time	−0.00 (0.00)	−0.00 (0.00)	0.00 (0.01)	0.05 (0.03)	−0.02 (0.02)	−0.02 (0.02)	−0.00 (0.02)
Pre-K sleep	0.00 (0.00)	−0.00 (0.00)	0.04 (0.03)	0.03 (0.05)	0.04 (0.04)	−0.01 (0.03)	−0.01 (0.03)
Pre-K sleep × time	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)	0.01 (0.02)	−0.01 (0.02)	0.02 (0.02)	0.00 (0.02)
BP sleep	−0.00 (0.01)	−0.00 (0.00)	0.07*** (0.03)	0.05 (0.05)	−0.02 (0.05)	0.04 (0.04)	0.01 (0.03)
Covariates							
Poverty line	0.13 (0.07)	−0.02 (0.03)	2.13** (0.45)	3.43** (0.62)	2.50** (0.65)	1.20*** (0.47)	0.35 (0.31)
Child health	0.02 (0.02)	0.00 (0.01)	0.12 (0.09)	0.03 (0.14)	−0.02 (0.14)	−0.06 (0.11)	0.02 (0.07)
Cohort	−0.05 (0.12)	−0.02 (0.04)	0.91 (0.78)	−1.43 (1.12)	1.30 (1.06)	0.47 (0.82)	0.45 (0.56)
Missed school days							
WP	−0.27*** (0.14)	−0.06 (0.11)	0.55 (0.66)	0.80 (1.18)	−3.88* (1.33)	−2.29*** (1.06)	−2.75* (1.0)
BP	−0.26 (0.34)	−0.16 (0.13)	−2.43 (2.00)	6.54* (2.50)	−0.45 (2.97)	−0.04 (2.09)	−0.91 (1.44)

Note: numbers in parentheses are standard errors. Time = time of assessment across the K year: pre-K (July–August), early K (September), mid-K (November), late K (April). Sleep = mean sleep duration per 24-hour period at each assessment point; sleep × time = interaction of sleep by time. Pre-K sleep = between-person sleep at pre-K only; pre-K sleep × time = interaction of pre-K sleep by time. WP deviations from one's cross-time average; between-person sleep averaged across all time points. *** P < .05, * P < .01, ** P < .001. ACES, Academic Competence Evaluation Scales; BP, between person; TOWRE, Test of Word Reading Efficiency; WISC III, Wechsler Intelligence Scales for Children, Third Edition.

children was Hispanic (8.6%). Children were evenly divided by biological sex (Table 1). Analyses examining each of the 3 sleep predictors appear in Tables 2–7. Daytime rest/sleep took place almost exclusively at pre-K (median number of days with naps = 1, interquartile range [IQR] = 0–3), and was rare once K started (median = 0, IQR = 0–1 at early K; median = 0, IQR = 0–1 at mid-K; and median = 0, IQR = 0–0 at late K). Covariates used in analyses were predictive of children's school outcomes as expected, with the largest part of prediction carried by socioeconomic risk. Cohort effects

TABLE 4 Multilevel Modeling Results Examining the Impact of the Regularity of 10-Plus Hours of Child Sleep Per 24-Hour Period on Child Outcomes in Kindergarten, Socioemotional and Learning Engagement Measures

| | Socioemotional Measures | | | Learning Engagement Measures | | | |
	Social Competence (SCS)	Aggression (TOCA-R)	Student–Teacher Relationship (STRS)	Learning Behaviors (LBS)	School Readiness (SRQ)	ADHD Symptoms	Task Orientation (TOS)
Intercept	31.48*** (2.29)	31.12* (1.06)	114.43* (2.91)	45.02* (1.91)	61.20* (2.64)	13.16* (2.12)	15.05* (0.70)
Time	0.11 (0.42)	−0.47 (0.19)	0.80 (0.51)	−0.22 (0.38)	−0.09 (0.60)	0.34 (0.36)	0.76* (0.17)
WP sleep	−4.25 (2.51)	−1.67 (1.13)	−2.42 (3.00)	−2.05 (2.27)	−0.45 (3.55)	1.54 (2.11)	−0.94 (1.03)
WP sleep × time	1.08 (1.77)	1.37 (0.80)	0.69 (2.12)	0.96 (1.60)	4.26 (2.49)	−1.17 (1.50)	0.96 (0.73)
Pre-K sleep	−3.87 (2.66)	−0.17 (1.26)	−4.41 (3.36)	4.19 (2.34)	−4.40 (3.39)	1.56 (2.57)	0.14 (0.93)
Pre-K sleep × time	1.12 (1.23)	−0.30 (0.55)	1.82 (1.47)	0.29 (1.11)	1.12 (1.74)	−1.13 (1.03)	0.51 (0.49)
BP sleep	6.59 (4.04)	1.58 (1.91)	4.18 (5.08)	4.05 (3.34)	−2.08 (5.15)	2.04 (3.84)	−0.11 (1.40)
Covariates							
Poverty line	1.11** (0.38)	0.33 (0.18)	0.99*** (0.48)	1.07** (0.33)	1.93* (0.47)	−0.88*** (0.37)	0.27*** (0.13)
Child health	0.13 (0.08)	0.04 (0.04)	0.23 (0.10)	0.16*** (0.07)	0.17 (0.10)	−0.11 (0.08)	0.02 (0.03)
Cohort	0.62 (0.68)	−0.30 (0.32)	0.95 (0.87)	0.88 (0.58)	0.92 (0.80)	−0.72 (0.65)	0.47*** (0.21)
Missed school days							
WP	2.06** (0.73)	0.78*** (0.33)	1.40 (0.87)	−0.22 (0.66)	0.29 (1.03)	−0.24 (0.62)	−0.65*** (0.32)
BP	−0.45 (1.71)	0.01 (0.82)	−0.24 (2.18)	−1.67 (1.49)	−1.60 (2.11)	0.41 (1.68)	−1.00 (0.57)

Note: numbers in parentheses are standard errors. Time = time of assessment across the K year: pre-K (July–August), early K (September), mid-K (November), late K (April). Sleep = proportion of 24-hour periods in which children slept 10 or more hours at each assessment point. Sleep × time = interaction of child sleep by time. Pre-K sleep = between-person sleep at pre-K only; pre-K sleep × time = interaction of pre-K sleep by time. WP deviations from one's cross-time average; between-person sleep averaged across all time points. * P < .001, ** P < .01, *** P < .05. BP, between person; LBS, Learning Behaviors Scale; SCS, Social Competence Scale; STRS, Student–Teacher Relationship Scale; TOCA-R, Teacher Observation of Classroom Adaptation, Revised.

TABLE 5 Multilevel Modeling Results Examining the Impact of the Regularity of 10-Plus Hours of Child Sleep Per 24-Hour Period on Child Outcomes in Kindergarten, Executive Functioning and Academic Measures

	Executive Functioning Measures		Academic Measures				
						TOWRE	
	Working Memory (WISC III)	Attentional Functioning (KCPT-2)	Academic Performance (APRS)	Academic Competence (ACES)	Letter Recognition (DIBELS)	Site Word Efficiency	Phonemic Decoding
Intercept	5.71* (0.39)	0.68* (0.16)	63.74* (2.55)	72.85* (3.74)	17.22* (3.60)	−3.81 (2.82)	−0.21 (2.10)
Time	0.41* (0.07)	0.04 (0.06)	0.28 (0.40)	2.78* (0.97)	14.42* (0.73)	10.38* (0.68)	4.69* (0.66)
WP sleep	−0.09 (0.45)	0.39 (0.37)	−1.51 (2.36)	−4.28 (5.87)	1.97 (4.37)	−0.15 (3.90)	1.90 (4.03)
WP sleep × time	−0.05 (0.32)	−0.33 (0.24)	0.73 (1.68)	4.39 (4.15)	−3.51 (3.14)	−1.60 (2.79)	−3.99 (2.66)
Pre-K sleep	−0.16 (0.52)	−0.22 (0.25)	−8.04** (3.13)	−2.95 (5.53)	−3.94 (4.73)	0.56 (4.07)	−3.14 (3.82)
Pre-K sleep × time	0.00 (0.22)	0.17 (0.17)	2.51*** (1.16)	0.39 (2.78)	1.85 (2.12)	−3.14 (1.96)	0.53 (2.01)
BP sleep	0.03 (0.76)	−0.02 (0.37)	8.66 (4.66)	4.93 (6.79)	7.09 (7.00)	7.80 (5.12)	5.43 (3.71)
Covariates							
Poverty line	0.12 (0.07)	−0.02 (0.03)	2.16* (0.46)	3.53* (0.65)	2.64* (0.67)	1.18*** (0.50)	0.40 (0.33)
Child health	0.02 (0.02)	0.00 (0.01)	0.14 (0.10)	0.09 (0.14)	−0.01 (0.14)	−0.06 (0.11)	0.03 (0.07)
Cohort	−0.07 (0.12)	−0.03 (0.05)	1.44 (0.80)	−0.94 (1.16)	1.49 (1.12)	0.63 (0.87)	0.59 (0.59)
Missed school days							
WP	−0.27 (0.14)	−0.05 (0.11)	0.66 (0.69)	1.15 (1.15)	−3.50*** (1.39)	−2.42*** (1.11)	−2.89** (1.03)
BP	−0.23 (0.34)	−0.15 (0.13)	−2.51 (2.07)	6.76** (2.57)	−0.67 (3.10)	−0.21 (2.19)	−1.03 (1.46)

Note: numbers in parentheses are standard errors. Time = time of assessment across the K year: pre-K (July–August), early K (September), mid-K (November), late K (April). Sleep = proportion of 24-hour periods in which children slept 10 or more hours at each assessment point. Sleep × time = interaction of child sleep by time. Pre-K sleep = between-person sleep at pre-K only; pre-K sleep × time = interaction of pre-K sleep by time. WP deviations from one's cross-time average; between-person sleep averaged across all time points. * P < .001, ** P < .01, *** P < .05. ACES, Academic Competence Evaluation Scales; BP, between person; TOWRE, Test of Word Reading Efficiency; WISC III, Wechsler Intelligence Scales for Children, Third Edition.

were in almost all cases not significant.

Analyses of Overall Mean Sleep Duration Per 24-Hour Period

Analyses of children's sleep duration per day, averaged across the full 7 days of data collection at each time point (Table 2), revealed scattered effects (*ps* < 0.05) of sleep on K outcomes. Teachers rated children with longer sleep per 24-hours higher on overall academic performance (the APRS; *d* = 0.44). Project staff rated children with longer 24-hour pre-K sleep to be more task-oriented throughout the year (TOS; *d* = 0.59), relative to children with shorter 24-hour sleep. Within-person (WP) sleep effects were found showing that, when

TABLE 6 Multilevel Modeling Results Examining the Impact of the Regularity of 10-Plus Hours Per Night of Child Sleep on Teacher-Rated Child Outcomes in Kindergarten, Socioemotional and Learning Engagement Measures

	Socioemotional Measures			Learning Engagement Measures			
	Social Competence (SCS)	Aggression (TOCA-R)	Student–Teacher Relationship (STRS)	Learning Behaviors (LBS)	School Readiness (SRQ)	ADHD Symptoms	Task Orientation (TOS)
Intercept	31.21* (2.33)	30.55* (1.08)	114.89* (2.95)	45.43* (2.00)	62.77* (2.80)	13.60* (2.15)	15.32* (0.74)
Time	0.97 (0.60)	−0.08 (0.27)	0.99 (0.72)	−0.24 (0.54)	−1.3 (0.84)	−0.02 (0.51)	0.86* (0.24)
WP sleep	1.06 (1.98)	0.73 (0.88)	0.89 (2.37)	−0.73 (1.77)	−2.78 (2.78)	−0.77 (1.67)	−0.87 (0.80)
WP sleep × time	−1.68 (1.35)	−0.43 (0.60)	−0.01 (1.61)	0.34 (1.20)	5.04** (1.88)	0.26 (1.14)	0.08 (0.54)
Pre-K sleep	5.95*** (2.60)	3.74** (1.24)	9.48** (3.26)	5.43*** (2.31)	10.65** (3.32)	−8.66** (2.49)	1.88*** (0.91)
Pre-K sleep × time	0.21 (1.26)	0.16 (0.56)	−0.27 (1.51)	0.20 (1.13)	−3.32 (1.76)	0.16 (1.06)	0.19 (0.50)
BP sleep	3.01 (3.19)	−1.13 (1.50)	3.28 (3.99)	1.04 (2.83)	1.01 (4.09)	1.69 (3.01)	0.88 (1.11)
Covariates							
Poverty line	1.10** (0.36)	0.34*** (0.17)	0.92*** (0.46)	1.12** (0.32)	1.98* (0.45)	−0.89*** (0.36)	0.27*** (0.12)
Child health	0.11 (0.07)	0.03 (0.04)	0.17 (0.09)	0.15*** (0.07)	0.13 (0.09)	−0.08 (0.07)	0.02 (0.03)
Cohort	0.25 (0.65)	−0.30 (0.31)	0.48 (0.83)	0.62 (0.57)	0.63 (0.78)	−0.59 (0.62)	0.44*** (0.20)
Missed school days							
WP	1.64*** (0.71)	0.69*** (0.31)	1.04 (0.84)	−0.28 (0.63)	0.35 (0.99)	−0.10 (0.60)	−0.67*** (0.31)
BP	−0.24 (1.61)	0.11 (0.77)	−0.12 (2.03)	−1.54 (1.42)	−1.90 (2.01)	0.41 (1.58)	−1.00 (0.57)

Note: numbers in parentheses are standard errors. Time = time of assessment across the K year: pre-K (July–August), early K (September), mid-K (November), late K (April). Sleep = proportion of nights of 10-plus hours of child sleep at each time of assessment. Sleep × time = interaction of child sleep by time. Pre-K sleep = between-person sleep at pre-K only; pre-K sleep × time = interaction of pre-K sleep by time. WP deviations from one's cross-time average; between-person sleep averaged across all time points. * P < .001, ** P < .01, *** P < .05. BP, between person; LBS, Learning Behaviors Scale; SCS, Social Competence Scale; STRS, Student–Teacher Relationship Scale; TOCA-R, Teacher Observation of Classroom Adaptation, Revised.

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TABLE 7 Multilevel Modeling Results Examining the Impact of the Regularity of 10-Plus Hours Per Night of Child Sleep on Teacher-Rated Child Outcomes in Kindergarten, Executive Functioning and Academic Measures

	Executive Functioning Measures		Academic Measures				
						TOWRE	
	Working Memory (WISC III)	Attentional Functioning (KCPT-2)	Academic Performance (APRS)	Academic Competence (ACES)	Letter Recognition (DIBELS)	Site Word Efficiency	Phonemic Decoding
Intercept	5.64* (0.42)	0.77* (0.19)	65.20* (2.56)	75.52* (3.99)	15.00* (3.70)	−4.88 (2.93)	0.78 (2.26)
Time	0.48* (0.11)	0.02 (0.08)	0.35 (0.57)	1.37 (1.39)	14.99* (1.03)	10.94* (0.94)	4.12* (0.86)
WP sleep	−0.10 (0.35)	−0.04 (0.29)	−2.10 (1.86)	−6.31 (4.47)	8.14*** (3.39)	2.18 (3.16)	−1.66 (3.12)
WP sleep × time	−0.19 (0.24)	0.00 (0.19)	0.06 (1.27)	5.26 (2.95)	−2.93 (2.29)	−2.26 (2.10)	−0.39 (2.03)
Pre-K sleep	0.16 (0.52)	−0.15 (0.26)	8.95** (3.02)	9.71 (5.35)	10.08*** (4.58)	6.71 (3.87)	4.51 (3.63)
Pre-K sleep × time	0.31 (0.22)	−0.06 (0.18)	0.92 (1.19)	0.84 (2.67)	0.55 (2.14)	2.20 (1.86)	0.22 (1.83)
BP sleep	−0.68 (0.62)	0.27 (0.30)	4.83 (3.60)	1.65 (5.71)	−1.91 (5.49)	−3.57 (4.29)	−1.93 (3.37)
Covariates							
Poverty line	0.14 (0.08)	−0.03 (0.03)	2.20* (0.44)	3.53* (0.61)	2.55* (0.65)	1.24** (0.48)	0.41 (0.32)
Child health	0.02 (0.02)	0.00 (0.01)	0.11 (0.09)	0.04 (0.13)	−0.04 (0.14)	−0.07 (0.11)	0.02 (0.07)
Cohort	−0.04 (0.12)	−0.03 (0.04)	0.97 (0.76)	−1.34 (1.11)	1.28 (1.07)	0.60 (0.83)	0.48 (0.57)
Missed school days							
WP	−0.29** (0.14)	−0.04 (0.11)	0.60 (0.66)	0.76 (1.13)	−3.58** (1.33)	−2.43*** (1.07)	−2.68** (1.01)
BP	−0.29 (0.34)	−0.15 (0.13)	−2.19 (1.93)	6.99** (2.44)	−0.27 (2.95)	0.10 (2.08)	−0.97 (1.44)

Note: numbers in parentheses are standard errors. Time = time of assessment across the K year: pre-K (July–August), early K (September), mid-K (November), late K (April). Sleep = proportion of nights of 10-plus hours of child sleep at each time of assessment. Sleep × time = interaction of child sleep by time. Pre-K sleep = between-person sleep at pre-K only; pre-K sleep × time = interaction of pre-K sleep by time. WP deviations from one's cross-time average; between-person sleep averaged across all time points. * $P < .001$, ** $P < .01$, *** $P < .05$. ACES, Academic Competence Evaluation Scales; BP, between person; TOWRE, Test of Word Reading Efficiency; WISC III, Wechsler Intelligence Scales for Children, Third Edition.

children's sleep per 24 hours was longer than their cross-time average, children performed better at letter recognition (the DIBELS; $d = 0.31$). In addition, but counterintuitively, when children slept longer than their cross-time average, teachers rated them lower on school readiness (the SRQ; $d = 0.29$). This effect was qualified by a WP sleep × time interaction ($d = 0.19$) indicating that this inverse relation decreased toward the end of the K year. The absence of a similar pattern in the other 2 sleep models suggest that this result be interpreted with caution.

Analyses of the Proportion of 24-Hour Periods in Which Children Slept 10-Plus Hours

Analyses of the proportion of 24-hour periods in which children slept 10 or more hours represented a test of the AASM's recommendations that 5-year-old children should get, minimally, 10 hours of sleep per 24 hours on a regular basis. These analyses (Table 4) revealed 1 significant ($P < .05$) but counterintuitive effect, specifically that more days of 10-plus hours of sleep at pre-K predicted lower academic performance across the year (APRS; $d = 0.15$). This effect was moderated, however, by time of assessment such that this relation became less negative across time ($d = 0.06$). No other linkages were found for any other K outcome.

Analyses of the Proportion of Nights Only in Which Children Slept 10 Or More Hours

Lastly, analyses were conducted on the proportions of night sleep only during which children slept 10 or more hours (Table 6). Analyses revealed that the weekly proportion of 10-plus hours of nightly sleep, particularly at pre-K, significantly and consistently predicted children's socioemotional, learning engagement, and selected academic outcomes across the full year ($ps < 0.05$). Children with more nights of 10-plus hours of pre-K sleep were rated more favorably by teachers on aggression
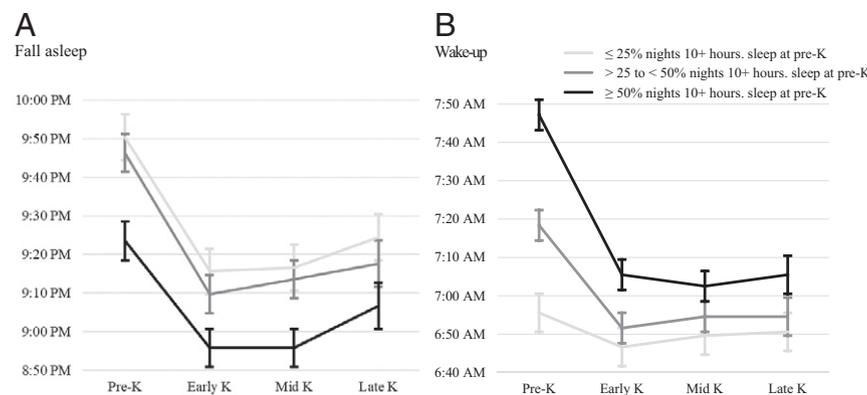
FIGURE 1
Adjusted mean fall asleep and wake-up times by sleep group formed at the pre-K time point. Sample data were split into top, middle, and bottom thirds on the basis of the total number of nights of 10 or more hours of sleep at the pre-K time point. Significant group differences in fall asleep (A) and wake-up (B) are indicated by error bars that do not overlap.

(Teacher Observation of Classroom Adaptation, Revised; d = 0.57), social competence (Social Competence Scale; d = 0.46), student–teacher relationships (Student–Teacher Relationship Scale; d = 0.57), classroom learning behaviors (Learning Behaviors Scale; d = 0.46), school readiness (SRQ; d = 0.64), and ADHD behavior (lower levels; d = 0.63). In addition, project staff rated children with more nights of 10-plus hours of pre-K sleep to be more task oriented (TOS; d = 0.39), again across the full K year, compared with children with less adequate sleep at pre-K. Children with more nights of 10-plus hours of pre-K sleep were also rated by teachers as showing higher levels of academic performance (APRS; d = 0.52) across the full year, and project staff rated children with more nights of 10-plus hours of sleep at pre-K to be better at letter naming (the DIBELS; d = 0.38) across the K year. This finding for letter naming was upheld across all measurement occasions across the K year (d = 0.88).

There were also 2 WP effects, such that when the proportion of 10-plus hours of nightly sleep exceeded children's cross-time average, their performance on letter recognition and teacher ratings of school readiness improved. No linkages emerged between child sleep and executive functioning (forward digit span) and attentional abilities (KCPT-2).

Further analyses examining the proportion of nights in which children slept 11 or more hours did not yield sufficient numbers of children who met that threshold. Indeed, it appeared that it was the regularity of children's 10-plus hours of nightly sleep, particularly at pre-K, that was most important in predicting children's adjustment to first-time schooling.

Pre- Versus Postkindergarten Nighttime Sleep Patterns

Analyses were then conducted to determine if findings changed with pre-K nighttime sleep removed from the model. These analyses revealed that removing pre-K sleep did not change substantive conclusions. We then explored whether individual differences in nighttime sleep regularity identified at pre-K persisted across the K year. Children were grouped into 3 categories: those with 10-plus hours of sleep on a quarter or fewer nights (insufficient sleep, n = 64), those with 10-plus hours of sleep on greater than a quarter but fewer than half of nights (intermediate sleep, n = 76), and those with 10-plus hours of sleep on greater than half of nights (sufficient sleep, n = 80).

Compared with the group with insufficient pre-K nighttime sleep, children in the sufficient sleep group tended to go to sleep earlier by about 26 minutes (P < .05, d = 0.39), and to wake up later by about 52 minutes (P < .05, d = 0.84) (Fig 1). There were no differences in variability in bedtimes or wake times. In addition, ps < 0.05), compared with the children in the other 2 pre-K sleep groups. Importantly, children in the pre-K sufficient sleep group continued to show better socioemotional and academic adjustment across the year, compared with the other 2 groups.

DISCUSSION

The current study demonstrated that, net of socioeconomic and health covariates, regularity of child sleep that is 10 or more hours per night, and in particular before the K year begins, broadly predicted children's K adjustment across the full year. Further, regularity of 10-plus hours of nighttime sleep was a more robust predictor of adjustment than overall levels of daily child sleep and regularity of

10-plus hours of sleep per 24 hours. Although AASM guidelines recommend 10 to 13 hours of sleep per 24 hours for children of K age,[13] the current study suggests that the more consistently at least 10 hours of sleep occur during the night, the better is children's adjustment.

Subsequent analyses revealed that children regularly getting 10-plus hours of nightly sleep at pre-K were significantly more likely to maintain this pattern of sufficient sleep across the K year, relative to the intermediate and insufficient sleep subgroups. These findings suggest that efforts to promote children's K adjustment should be especially attuned to child sleep before K start. Good sleep hygiene (eg, organized bedtime routines, limited screen access, and bedtimes before 9 PM) may be as critical for the well-being of children as it is for adults.[33–38] Consistent with previous work,[2,22] analyses also revealed the ubiquitous, negative effects of socioeconomic risk on K outcomes, and thus improving pre-K sleep habits among children living in socioeconomically stressed environments may be especially important.

We further propose that such interventions target parental, as well as child, sleep because sleep between parents and children (eg, bedtimes, sleep onset, and morning wake-ups) are closely aligned.[35] Such interventions may need to be flexibly adapted, especially when parents have irregular, nonstandard work hours.[39]

LIMITATIONS

The current study had several limitations. In some cases, we were unable to obtain 7 nights of actigraphy data because Actiwatches had been removed from the child's wrist for >60 minutes. In addition, although actigraphy objectively assesses sleep–wake activity,[40] it is not as precise as polysomnography in distinguishing sleep from nonactive

rest periods.[17] Third, despite oversampling of racial and ethnic minority families, the present sample remained predominantly White (76.9%), placing limits on generalizability. Fourth, the absence of linkages between child sleep and executive functioning was unexpected,[41] The KCPT-2 and our working memory task (forward digit span) may not have been sensitive to variations in child sleep duration. Fifth, the current study's findings are limited to sleep duration and cannot be generalized to other sleep characteristics such as fragmentation, efficiency, and night awakenings. Lastly, child sleep can be impacted by a host of factors not assessed in this study, including weight, BMI, chronic snoring, asthma, and sleep disordered breathing/sleep apnea.

CONCLUSIONS

Net of socioeconomic and health covariates, children who regularly obtained 10-plus hours of sleep per night, particular before K onset, transitioned more successfully to K than children with less-regular sleeping patterns. These effects were ubiquitous, extending to socioemotional, learning engagement, and academic domains. Regularity of sufficient nighttime sleep appeared to be more important for school adjustment than overall amounts of sleep across the day or the proportion of 24-hour periods in which children got 10 or more hours of sleep. Findings suggest that family-based interventions to establish consistent patterns of sufficient nighttime sleep should begin well before (eg, 5–6 months) the start of K.

ABBREVIATIONS

AASM: American Academy of Sleep Medicine
ADHD: attention-deficit/ hyperactivity disorder
APRS: Academic Performance Rating Scale
DIBELS: Dynamic Indicators of Basic Early Literacy Skills
IQR: interquartile range
K: kindergarten
KCPT-2: Kiddie Continuous Performance Test
SRQ: school readiness questionnaire
TOS: task orientation scale
WP: within person

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