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Adolescent sleep duration and timing during early COVID-19 school closures



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ABSTRACT

Objectives: To investigate adolescent sleep parameters and predictors during COVID-19-related school closures. **Methods:** Original data were analyzed from a cross-sectional online survey of 590 teens in grades 6–12 attending school remotely in 35 US states, in May/June 2020.

Results: Students reported waking up 2.1–2.9 hours later during school closures and averaged 7.9–8.7 hours of sleep and 8.6–9.5 hours in bed on school nights. Compared to middle schoolers, high school students had later bed and wake times, accompanied by spending less time in bed and less time sleeping. The delay in wake time after school closures was also longer for high school students than for middle schoolers. Students with later class start times went to bed later, but also woke up later, slept longer, and spent more time in bed. When comparing intraindividual sleep before and after school closures, later class start times resulted in greater delays in wake time and greater odds of increased sleep duration. In addition, parent-set bedtimes were associated with earlier bedtimes and longer sleep duration during school closures.

Conclusions: As a result of COVID-19-related school closures and remote instruction, more middle and high school students achieved recommended amounts of sleep, primarily by waking up later in the morning. This study supports previous evidence that morning start schedule affects adolescent sleep behaviors. The implications of this study extend beyond COVID-19 school closures; adolescent sleep health improves with later school start times and fewer scheduled morning activities.

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Introduction

Sleep health for adolescents is a national priority.¹ Short sleep duration in this age group is associated with poor physical health, mental health, and academic performance.² Fewer than 30% of teens reported sufficient nightly sleep before the COVID-19 pandemic, due to physiological factors (eg, phase delay), behavioral factors (eg, screen time), and environmental constraints (eg, early high school start times).³ During the first few months of the COVID-19 pandemic, nearly all school districts across the United States closed, dramatically altering the schedules of at least 55.1 million teens.⁴

The transition to virtual learning removed a major constraint on teens' wake times and affected behaviors associated with sleep duration, timing, and quality, such as increased screen time and reduced daily structure, physical activity, exposure to natural light, and mental health.^{5–10} Early evidence indicated that teens were getting more sleep during the pandemic. One study found that 84% of adolescents reported sleeping seven or more hours per night while attending school online during the pandemic, compared to only 55% of a comparable sample in 2018.⁸ A longitudinal study comparing sleep before and during the COVID-19 pandemic among 122 adolescents found delayed weekday bedtimes (1 hour) and wake times (1.5 hours), increased weekday sleep duration, and decreased daytime sleepiness during the pandemic.¹¹ A cross-sectional study conducted in Italy reported significant delays in bedtimes and wake times as well.¹² Additionally, a qualitative study in adolescents found a 2-hour shift toward eveningness in pandemic sleep schedules, longer sleep

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duration, improved sleep quality, and reduced daytime sleepiness compared to prepandemic sleep.¹³ However, these studies did not examine whether school start times changed or remained the same for students in the sample during the pandemic, despite prior evidence on school start times' influence on adolescent sleep.¹⁴

Healthy sleep is particularly important during the COVID-19 pandemic to help adolescents cope with stress, maintain focus, and engage in online classes. In this brief report, we provide descriptive data on adolescent sleep during COVID-19-related school closures, as well as self-reported changes in sleep patterns. We hypothesized that with the transition to remote learning and disruption of established morning schedules, students' wake times would be later during school closures and sleep duration would be longer compared to prepandemic sleep patterns. Other predictors of adolescent sleep behaviors during COVID-19 school closures, such as class start time and parent-set bedtime, are also examined.

Methods

Study design and participants

A cross-sectional, anonymous online survey was distributed via e-mail and social media to a convenience sample of middle and high school students (grades 6–12) through a network of local Start School Later chapters across the United States.¹⁵ Chapter leaders were given a one-page explanatory flyer with a survey link to distribute widely to local parents, and recipients were encouraged to share the survey with interested students. The survey was open from May 7 to June 30, 2020. The instrument was adapted from the School Sleep Habits Survey¹⁶ and administered electronically in approximately 15–20 minutes using SurveyGizmo (now Alchemer).¹⁷

Because this study only uses fully de-identified data collected anonymously online, it was determined as "exempt" from review by the Emory University and Stony Brook University Institutional Review Boards.

Measures

Outcome measures: Sleep

Six sleep outcomes during school closures included: weekday bedtime, wake time, sleep duration, time in bed (TIB), sufficient sleep duration, and sufficient TIB. Sleep duration was reported by participants as the estimated number of hours slept per weeknight, and TIB was calculated as the difference between self-reported weekday bedtimes and wake times. Sufficient sleep duration and sufficient TIB were both determined using the National Sleep Foundation's consensus recommended hours of sleep (9+ hours for children aged 6–13 years, 8+ hours for teens aged 14–17 years, and 7+ hours for adults over 18 years), though the literature informing these recommendations often does not distinguish between TIB and sleep duration.¹⁸

Two additional outcomes comparing sleep before and after school closures included changes in weekday wake time and changes in sleep duration. Change in wake time was calculated as the difference between weekday wake time before school closure and after school closure, and participants categorically evaluated changes to their sleep duration since school closures (ie, more sleep = 1, less sleep or about the same = 0).

Covariates

Participants reported their gender identity, race/ethnicity, grade, difficulty falling or staying asleep, caffeine use, existence of a parent-imposed bedtime, and the time of their earliest synchronous (live) class. Additional details on predictor variables can be found in [Tables 1–3](#).

Statistical analyses

Descriptive statistics were examined for the full sample as well as by grade category, including middle school (6th–8th grade), early high school (9th–10th grade), and late high school (11th–12th grade). Analyses included 8 multivariate regression models. Continuous outcome variables (weekday bedtime, wake time, sleep duration, TIB, and change in wake time) were assessed using ordinary least squares regression. Three categorical outcomes (sufficient vs. insufficient sleep duration, sufficient vs. insufficient TIB, and increase in sleep duration since school closures vs. no increase) were assessed using logistic regression with results reported as odds ratios (OR). For all analyses, the models adjusted for participants' gender, race/ethnicity, grade category, difficulty falling or staying asleep, change in caffeine use, reporting a parent-imposed bedtime, and earliest start time for a live class (7:30–8:15 AM, 8:30–9:00 AM, 9:15 AM or later, or no designated start time). All regression models assessed statistical significance for each predictor at the alpha 0.05 level. All linear regression models met assumptions of normality and displayed no heteroskedasticity upon visual examination of residual and quantile-quantile plots. None of the predictors met conditions for collinearity, which was assessed using variance inflation factors. All data were analyzed in SAS 9.4 (SAS Institute, Cary, NC).

Results

Demographics and sleep

Analyses include data from 590 middle and high school students (grades 6–12) attending remote schooling in 35 US states ([Table 1](#)). Approximately 8.6% of the sample had synchronous classes, 18.8% had asynchronous classes, and 72.5% had a combination of the 2 learning modalities. During school closures, participants' synchronous class start times varied, with 17.1% starting between 7:30 and 8:15 AM, 20.2% starting between 8:30 and 9:00 AM, 35.6% starting at 9:15 AM or later, and 27.1% with no designated start time (including those without synchronous classes).

Across the entire sample, average weekday sleep duration was 8.2 ± 1.5 hours, and average TIB was 9.0 ± 1.5 hours during school closures. Approximately 60.7% of 6th–8th graders, 60.2% of 9th–10th graders, and 67.0% of 11th–12th graders reported sufficient weeknight sleep duration, while 76.1%, 75.6%, and 79.8% respectively reported sufficient weeknight TIB. During school closures, students in lower grades went to bed earlier, woke up earlier, slept longer, and spent more TIB than did older students (all p values $< .0001$). Students reported rising early prior to the pandemic (mean of 6:20 AM) and reported later wake times during school closures (mean of 8:58 AM). On average, students reported waking 2.6 (± 1.6) hours later during school closures compared to their prepandemic wake times, with high schoolers reporting a greater delay in wake time (2.9 hours) than middle schoolers (2.1 hours) ($p < .0001$). The vast majority of participants (93.5%) reported delayed wake times during school closures, and nearly three-quarters (74.2%) reported delayed bedtimes during school closures.

Multivariate models

Five linear regression models were run with the following outcomes: (M1) weekday wake time during school closures, (M2) weeknight bedtime during school closures, (M3) weeknight sleep duration during school closures, (M4) weeknight TIB during school closures, and (M5) change in weekday wake time from before to after school closures ([Table 2](#)). Three logistic regressions modeling the odds of (M6) sufficient sleep duration, (M7) sufficient TIB, and (M8) increased sleep duration from before to after school closures were also performed ([Table 3](#)).

Table 1
Sample demographics and adolescent sleep behaviors prior to and during COVID-19 school closures, by grade category

Variables	Full sample, n = 590	Middle school (6th–8th grade), n = 201	Early high school (9th–10th grade), n = 201	Late high school (11th–12th grade), n = 188
	N (%) or mean (SD)	N (%) or mean (SD)	N (%) or mean (SD)	N (%) or mean (SD)
Age	15.0 (1.9)	12.9 (0.9)	15.2 (0.8)	17.1 (0.7)
Gender, N (%)				
Male	243 (41.2%)	96 (47.8%)	70 (34.8%)	77 (41.0%)
Female	347 (58.8%)	105 (52.2%)	131 (65.2%)	111 (59.0%)
Race, N (%)				
Asian, NH	61 (10.3%)	9 (4.5%)	37 (18.4%)	15 (8.0%)
Black, NH	21 (3.6%)	7 (3.5%)	7 (3.5%)	7 (3.7%)
Hispanic	56 (9.5%)	14 (7.0%)	15 (7.5%)	27 (14.4%)
White, NH	421 (71.4%)	156 (77.6%)	136 (67.7%)	129 (68.6%)
Multiple/other, NH	31 (5.3%)	15 (7.4%)	6 (3.0%)	10 (5.3%)
Weekday wake time, before closures*	6:20 AM (0.6 h)	6:28 AM (0.6 h)	6:12 AM (0.6 h)	6:20 AM (0.7 h)
Weekday wake time, after closures*	8:58 AM (1.6 h)	8:32 AM (1.5 h)	9:09 AM (1.6 h)	9:13 AM (1.6 h)
Weeknight bedtime, after closures*	11:58 PM (1.7 h)	11:03 PM (1.6 h)	12:16 AM (1.4 h)	12:38 AM (1.5 h)
Weeknight sleep duration, after closures*	8.2 h (1.5 h)	8.7 h (1.5 h)	8.0 h (1.6 h)	7.9 h (1.4 h)
Weeknight time in bed, after closures*	9.0 h (1.5 h)	9.5 h (1.3 h)	8.9 h (1.6 h)	8.6 h (1.3 h)
Change in weekday wake time, before to after closures*	2.6 h (1.6 h)	2.1 h (1.5 h)	2.9 h (1.6 h)	2.9 h (1.5 h)
Increase in sleep duration, before to after closures, N (%)*	466 (79.0%)	134 (66.7%)	171 (85.1%)	161 (85.6%)
Delayed bedtime, before to after closures, N (%)	437 (74.2%)	142 (71.0%)	156 (77.6%)	139 (73.9%)
Delayed wake time, before to after closures, N (%)*	550 (93.5%)	181 (90.1%)	190 (95.0%)	179 (95.7%)
Sufficient sleep duration, after closures, N (%)	369 (62.5%)	122 (60.7%)	121 (60.2%)	126 (67.0%)
Sufficient time in bed, after closures, N (%)	455 (77.1%)	153 (76.1%)	152 (75.6%)	150 (79.8%)

NH = non-Hispanic.

* ANOVA or chi-square test indicated significant differences across the three grade categories (*p* value < .05).

Table 2
Predictors of adolescent sleep behaviors during covid-19 school closures, linear models

Predictor Variables	Model 1: Weekday wake time (min), post-closures		Model 2: Weeknight bedtime (min), post-closures		Model 3: Weeknight sleep duration (min), post-closures		Model 4: Weeknight time in bed (min), post-closures		Model 5: Change in weekday wake time (min), pre- to post-closures	
	B	95% CI	B	95% CI	B	95% CI	B	95% CI	B	95% CI
Adjusted R²	0.19***		0.33***		0.19***		0.16***		0.21***	
Intercept	7:37 am	(7:10, 8:04)	10:58 pm	(10:33, 11:24)	504.8	(479.1, 530.5)	518.5	(493.7, 543.4)	75.1	(48.8, 101.4)
Grade category										
Middle school	-	-	-	-	-	-	-	-	-	-
Early high school	24.3**	(6.2, 42.5)	46.6***	(29.2, 64.0)	-32.4***	(-49.8, -14.9)	-22.2**	(-39.1, -5.4)	41.0***	(23.1, 58.8)
Late high school	22.7*	(4.0, 41.4)	54.8***	(36.9, 72.7)	-23.2*	(-41.1, -5.2)	-32.1***	(-49.5, -14.8)	32.8***	(14.4, 51.1)
Gender										
Female	-	-	-	-	-	-	-	-	-	-
Male	8.5	(-6.7, 23.6)	9.5	(-5.0, 24.0)	0.2	(-14.3, 14.8)	-1.0	(-15.1, 13.1)	-4.0	(-18.9, 10.9)
Race/ethnicity										
White	-	-	-	-	-	-	-	-	-	-
Asian, NH [^]	9.9	(-14.1, 33.8)	20.9	(-2.0, 43.8)	-5.7	(-28.7, 17.4)	-11.1	(-33.3, 11.2)	4.8	(-18.7, 28.4)
Black, NH	4.2	(-33.8, 42.3)	1.5	(-34.9, 37.9)	-41.9*	(-78.5, -5.3)	2.7	(-32.7, 38.1)	8.1	(-29.3, 45.5)
Hispanic	-3.3	(-28.0, 21.3)	18.5	(-1.1, 42.0)	-26.1*	(-49.8, -2.4)	-21.8	(-44.6, 1.1)	-3.9	(-28.1, 20.3)
Multiple/other, NH	-12.5	(-44.3, 19.4)	-1.3	(-31.7, 29.1)	-10.7	(-41.3, 19.9)	-11.2	(-40.7, 18.4)	-6.7	(-37.9, 24.6)
Earliest synchronous class time										
7:30–8:15 AM	-	-	-	-	-	-	-	-	-	-
8:30–9:00 AM	16.1	(-7.2, 39.4)	-10.6	(-32.9, 11.7)	17.4	(-5.0, 39.8)	26.7*	(5.0, 48.3)	12.9	(-10.0, 35.8)
9:15 AM or later	77.3***	(56.4, 98.1)	33.1**	(13.2, 53.1)	37.7***	(17.7, 57.8)	44.1***	(24.8, 63.5)	62.5***	(42.0, 83.0)
No set start time	83.6***	(61.7, 105.5)	25.4*	(4.5, 46.4)	48.9***	(27.8, 69.9)	58.2***	(37.8, 78.5)	79.2***	(57.7, 100.7)
Parent-set bedtime										
No	-	-	-	-	-	-	-	-	-	-
Yes	-33.7***	(-53.0, -14.3)	-83.5***	(-102.0, -65.0)	33.0***	(14.4, 51.6)	49.9***	(31.9, 67.8)	-28.4**	(-47.4, -9.4)
Trouble going or staying asleep (past 2 weeks)										
Never	-	-	-	-	-	-	-	-	-	-
Once	-13.4	(-36.6, 9.8)	-17.7	(-39.9, 4.5)	-6.4	(-28.7, 16.0)	4.3	(-17.3, 25.9)	-6.8	(-29.6, 16.0)
Twice	17.2	(-4.9, 39.2)	1.3	(-19.8, 22.5)	-11.9	(-33.1, 9.4)	15.8	(-4.7, 36.3)	16.6	(-5.1, 38.3)
Several times	10.8	(-7.4, 29.0)	16.2	(-1.3, 33.6)	-38.1***	(-55.6, -20.6)	-5.4	(-22.3, 11.6)	16.7	(-1.2, 34.6)
Every day/night	35.8**	(10.0, 61.6)	49.1***	(24.5, 73.8)	-78.3***	(-103.1, -53.5)	-13.3	(-37.3, 10.6)	45.8***	(20.5, 71.2)
Change in caffeine use during school closures										
Never used caffeine	-	-	-	-	-	-	-	-	-	-
More caffeine use	21.6	(-0.8, 44.1)	22.8*	(1.3, 44.3)	-9.4	(-30.9, 12.2)	-1.2	(-22.0, 19.7)	18.7	(-3.4, 40.7)
Same caffeine use	9.0	(-9.8, 27.7)	17.3	(-0.7, 35.2)	-18.4*	(-36.4, -0.4)	-8.3	(-25.7, 9.1)	12.2	(-6.3, 30.6)
Less caffeine use	12.6	(-6.9, 32.0)	22.0*	(3.4, 40.6)	-2.9	(-21.6, 15.8)	-9.4	(-27.5, 8.6)	16.2	(-2.9, 35.3)

* *p*-value < .05

** *p*-value < .01

*** *p*-value < .001

[^] NH = non-Hispanic

Table 3
Predictors of adolescent sleep behaviors during COVID-19 school closures, logistic models

Predictor variables	Model 6: Sufficient sleep duration, after closures		Model 7: Sufficient time in bed, after closures		Model 8: Increase in sleep duration, before to after closures	
	OR	95% CI	OR	95% CI	OR	95% CI
Grade category						
Middle school	-	-	-	-	-	-
Early high school	1.2	(0.8, 1.9)	1.3	(0.8, 2.1)	2.9***	(1.7, 4.9)
Late high school	2.1**	(1.3, 3.4)	2.0*	(1.1, 3.4)	2.9***	(1.7, 5.1)
Gender						
Female	-	-	-	-	-	-
Male	1.3	(0.9, 1.9)	1.1	(0.7, 1.7)	1.4	(0.9, 2.2)
Race/ethnicity						
White	-	-	-	-	-	-
Asian, NH [^]	1.1	(0.6, 2.0)	0.7	(0.4, 1.3)	1.1	(0.5, 2.3)
Black, NH	0.6	(0.2, 1.7)	1.0	(0.3, 3.0)	1.1	(0.4, 3.2)
Hispanic	0.6	(0.3, 1.1)	0.5*	(0.2, 0.9)	1.3	(0.6, 2.8)
Multiple/other, NH	1.1	(0.5, 2.4)	0.9	(0.4, 2.3)	1.0	(0.4, 2.5)
Earliest synchronous class time						
7:30–8:15 AM	-	-	-	-	-	-
8:30–9:00 AM	0.9	(0.5, 1.5)	2.2*	(1.2, 4.1)	1.2	(0.6, 2.3)
9:15 AM or later	2.0**	(1.2, 3.4)	3.1***	(1.8, 5.4)	2.2*	(1.2, 4.1)
No set start time	2.3**	(1.3, 4.0)	4.1***	(2.2, 7.6)	1.7	(0.9, 3.1)
Parent-set bedtime						
No	-	-	-	-	-	-
Yes	2.4**	(1.4, 4.0)	2.3***	(1.2, 4.4)	1.0	(0.6, 1.7)
Trouble going or staying asleep (past 2 weeks)						
Never	-	-	-	-	-	-
Once	0.9	(0.5, 1.7)	1.1	(0.6, 2.3)	1.2	(0.6, 2.5)
Twice	0.7	(0.4, 1.2)	1.3	(0.7, 2.6)	1.9	(0.9, 4.0)
Several times	0.4***	(0.3, 0.7)	0.9	(0.5, 1.6)	0.9	(0.5, 1.6)
Every day/night	0.2***	(0.1, 0.5)	0.5*	(0.2, 0.9)	0.5	(0.3, 1.1)
Change in caffeine use during school closures						
Never use caffeine	-	-	-	-	-	-
More caffeine use	0.8	(0.5, 1.4)	0.7	(0.4, 1.4)	0.6	(0.3, 1.1)
Same caffeine use	0.7	(0.5, 1.2)	0.7	(0.4, 1.2)	1.1	(0.6, 1.9)
Less caffeine use	1.0	(0.6, 1.6)	0.8	(0.5, 1.5)	2.0*	(1.0, 4.1)

[^] NH = non-Hispanic.

* *p* value < .05.

** *p* value < .01.

*** *p* value < .001.

In all linear regression models, grade category and parent-set bedtime significantly predicted the respective sleep outcome. Compared to middle schoolers, high schoolers woke up later (**M1**, $B_{9-10th} = 24$ minutes, 95% confidence interval [CI] [6, 43]; $B_{11-12th} = 22$ minutes, 95% CI [4, 41]) and went to bed later (**M2**, $B_{9-10th} = 47$ minutes, 95% CI [29, 64]; $B_{11-12th} = 55$ minutes, 95% CI [37, 73]). High schoolers also had shorter sleep duration (**M3**, $B_{9-10th} = -32$ minutes, 95% CI [-50, -15]; $B_{11-12th} = -23$ minutes, 95% CI [-41, -5]) and TIB (**M4**, $B_{9-10th} = -22$ minutes, 95% CI [-39, -5]; $B_{11-12th} = -32$ minutes, 95% CI [-49, -15]) during school closures, and had a greater change in weekday wake time from before to after school closures (**M5**, $B_{9-10th} = 41$ minutes, 95% CI [23, 59]; $B_{11-12th} = 33$ minutes, 95% CI [14, 51]). Parent-set bedtime was associated with going to bed earlier (**M2**, $B = -84$ minutes, 95% CI [-102, -65]), waking up earlier (**M1**, $B = -34$ minutes, 95% CI [-47, -9]), and longer sleep duration (**M3**, $B = 33$ minutes, 95% CI [14, 52]) and TIB (**M4**, $B = 50$ minutes, 95% CI [32, 68]) during school closures, as well as a smaller change in wake time from before to after school closures (**M5**, $B = -28$ minutes, 95% CI [-47, -9]).

The time of students' earliest synchronous classes also predicted sleep outcomes in most models. Those starting class at 9:15 AM or later and those with no set start time woke up later (**M1**, $B_{9:15} = 77$ minutes, 95% CI [56, 98]; $B_{No\ set\ start} = 84$ minutes, 95% CI [62, 105]) and went to bed later (**M2**, $B_{9:15} = 33$ minutes, 95% CI [13, 53]; $B_{No\ set\ start} = 25$ minutes, 95% CI [4, 46]) during school closures than those starting class between 7:30 and 8:15 AM. Students with later remote learning start times also had longer sleep duration (**M3**, $B_{9:15} = 38$ minutes, 95% CI [18, 58]; $B_{No\ set\ start} = 49$ minutes, 95% CI [28, 70]) and TIB (**M4**, $B_{8:30} = 27$ minutes, 95% CI [5, 48], $B_{9:15} = 44$ minutes,

95% CI [25, 63]; $B_{No\ set\ start} = 58$ minutes, 95% CI [38, 79]) during school closures and a greater change in wake time from before to after closures (**M5**, $B_{9:15} = 63$ minutes, 95% CI [42, 83]; $B_{No\ set\ start} = 79$ minutes, 95% CI [58, 101]).

In all logistic regression models, grade category and earliest synchronous class time were significant predictors. Late high schoolers had higher odds of obtaining sufficient sleep duration (**M6**, $OR_{11-12th} = 2.1$, 95% CI [1.3, 3.4]) and sufficient TIB (**M7**, $OR_{11-12th} = 2.0$, 95% CI [1.1, 3.4]) compared to middle schoolers after closures. As earliest synchronous class time delayed, the odds of obtaining sufficient sleep duration increased (**M6**, $OR_{9:15} = 2.0$, 95% CI [1.2, 3.4]; $OR_{No\ set\ start} = 2.3$, 95% CI [1.3, 4.0]) and odds of obtaining sufficient TIB increased (**M7**, $OR_{8:30} = 2.2$, 95% CI [1.2, 4.1]; $OR_{9:15} = 3.1$, 95% CI [1.8, 5.4]; $OR_{No\ set\ start} = 4.1$, 95% CI [2.2, 7.6]). The odds of reporting increased sleep duration during school closures were nearly three times higher among high schoolers than middle schoolers (**M8**, $OR_{9-10th} = 2.9$, 95% CI [1.7, 4.9]; $OR_{11-12th} = 2.9$, 95% CI [1.7, 5.1]). Students starting class at 9:15 AM or later had more than twice the odds of reporting an increase in sleep duration compared to those with a remote learning start time between 7:30 and 8:15 AM (**M8**, $OR = 2.2$, 95% CI [1.2, 4.1]). Having a parent-set bedtime also increased the odds of obtaining sufficient sleep duration (**M6**, $OR = 2.4$, 95% CI [1.4, 4.0]) and sufficient TIB (**M7**, $OR = 2.3$, 95% CI [1.2, 4.4]) after closures.

Discussion

With the closing of in-person schooling, students woke up later and slept longer. Bedtimes and wake times were progressively later

in higher grades, consistent with circadian rhythm changes with age.¹⁹ School closures had a larger effect on high schoolers than middle schoolers, with over 85% of high school students reporting increased sleep duration since COVID-19 and a 2.9-hour mean delay in weekday wake time. The delay in wake times reported by study participants (2.1–2.9 hours) exceeds that found by Becker et al (1.5 hours),¹¹ likely because students enrolled in the latter study did not experience delays in school start time. Sleep duration ranged from a mean of 8.7 hours for middle schoolers, to 8.0 hours for 9th and 10th graders, and 7.9 hours for 11th and 12th graders while mean TIB was 9.5 hours, 8.9 hours, and 8.6 hours, respectively. Only 39.3% of middle schoolers and 36.5% of high schoolers reported insufficient sleep duration during school closures, compared to 57.8% and 72.7% respectively among students taking the Youth Risk Behavior Survey (YRBS) prior to the pandemic.³ These findings are consistent with those of Becker et al,¹¹ as 36% of their sample of 10th graders reported insufficient sleep during COVID-19.

The results of this study confirm other researchers' findings that school start time is a major external influence on adolescent sleep behaviors.^{20–22} Students with earlier synchronous class start times slept less, spent less TIB, had reduced odds of obtaining sufficient sleep duration and TIB, and had smaller changes in weekday wake times during COVID-19 school closures. These findings support the American Academy of Pediatrics' recommendation that middle and high schools start classes at 8:30 AM or later to improve adolescent sleep.²³ The data are also consistent with previous literature on the impact of parent involvement in regulating adolescent sleep habits.²⁴ While parent-set bedtimes were more common among younger participants, on average, participants with parent-set bedtimes went to bed 1.4 hours earlier and reported an additional 30 minutes of sleep duration and 45 minutes of TIB on weekdays. The effect of parental involvement in bedtime and sleep duration is particularly notable given teens' reduced daily structure during COVID-19-related closures.

This study's strengths include its geographic diversity and use of a validated instrument slightly modified to fit these unusual circumstances. Limitations include its cross-sectional design, which did not allow for collection of data on bedtimes, sleep duration, and TIB prior to school closures, and reliance on self-reported sleep measures, which may be subject to recall bias. The majority of students were non-Hispanic white and female, which may hinder generalizability.

COVID-19 school closures afforded a unique opportunity to study adolescent sleep, as they disrupted long-established patterns and practices such as early school start times, bus pickups, commutes, and morning extracurricular activities. Due to school closures, adolescents in this study experienced a 2.1- to 2.9-hour delay in wake time, resulting in an increased proportion obtaining recommended amounts of sleep and providing further evidence that many middle and high school students would benefit if schools adopted healthy school start times.

Declaration of conflict of interest

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