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REVIEW ARTICLES

Middle school start times and young adolescent sleep, behavioral health, and academic performance outcomes: a narrative review

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Study Objectives: This narrative review aims to synthesize peer-reviewed and gray literature research that associates middle school start times to adolescent sleep, health, and academic performance.

Methods: A systematic search of publications in PubMed, Scopus, ERIC, APA PsycInfo, CINAHL, ProceedingsFirst, and ProQuest Dissertations and Theses from 2002–2020 was conducted. Studies with middle school students that had either an empirical evaluation of the implementation of a change in school start time or a comparison of schools with different school start times, and which also reported outcomes related to sleep and health and quantitative academic measures were included. School characteristics, student demographics, study design, start times, and outcomes were extracted from the full-text review.

Results: The review identified 1,136 articles; after removing duplicates, 845 were screened. Following title and abstract review, 18 articles were eligible for full-text review. Nine studies did not meet inclusion criteria. Half of the reviewed 10 studies used cross-sectional designs, 8 evaluated sleep, 6 evaluated behavioral health, and 3 evaluated academic performance.

Conclusions: Late middle school start times can improve adolescents' sleep and reduce daytime sleepiness by increasing total sleep time and delaying waketime. The current studies provide promising evidence that late-start times can improve tardiness, executive function, negative affect and mood, grade-point average, and standardized test scores. Methodologically robust research on delayed middle school start times can inform public policy and promote change.

Keywords: school health, sleep, school start times, middle school, young adolescents, education policy

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INTRODUCTION

A position statement by the American Academy of Pediatrics,[1] endorsed by the American Academy of Sleep Medicine,[2] the American Medical Association,[3] and the Centers for Disease Control and Prevention,[4] stated that middle and high schools should not start before 8:30 AM, yet nearly half of schools begin earlier than the recommended time. Of 39,000 public middle and high schools in the United States, only 17.7% start after the recommended school start time (SST) of 8:30 AM.[4,5] Decades of research have found that high schools that start at 8:30 AM or later, or that make dramatic shifts in their start time, benefit students' sleep, behavioral health, and academics. Late school start times provide high schoolers an opportunity for more sleep by delaying waketime.[6,7] High school students attending late-starting schools have less daytime sleepiness,[7,8] better attendance, less tardiness,[7,9] faster reaction times on performance testing,[10] improved mood,[11] and higher standardized test scores and grade point averages (GPA) than students attending earlier-starting schools.[7,12]

Two related aspects of sleep are associated with the benefits of late SST for high schoolers: circadian rhythms and total sleep time (TST). Adolescent circadian rhythms create later sleep drive, meaning later bedtimes and waketimes than younger children or adults.[13] Early SSTs are inconsistent with adolescent circadian rhythms and subsequently result in insufficient total sleep, because the later sleep drives of adolescents inhibit going to sleep early enough to obtain sufficient sleep. Because insufficient sleep results in adolescent sleep deprivation, daytime sleepiness, and associated health conditions, the impact of early SSTs is a public health issue.[1]

Little is known about the impact of SST on middle schoolers. Puberty onset occurs during middle school years, so it is possible that optimal SSTs for middle schoolers is consistent with that of high schoolers. However, there could be sex differences. Middle school typically begins around age 11, which is the median age of onset of puberty for girls, but a year earlier than puberty onset for boys.[14] It is also unclear whether SST impacts total sleep for middle schoolers. The recommended total sleep for children aged 6- to 13-years-old is 9–11 hours, whereas the recommended sleep for adolescents aged 14–17 is approximately 8–10 hours.[15] Possibly, because of their need for more sleep, middle schoolers may have benefits similar to those of high schoolers when SSTs are delayed. To date, no narrative review has examined the impact of SST on middle schoolers. The current narrative review is a first step in determining whether middle schoolers benefit from late SST and may be helpful for guiding policies regarding middle school start times.

METHODS

Selection criteria

The current narrative review used 7 electronic databases: PubMed, Scopus, ERIC (EBSCO), APA PsycInfo (EBSCO), CINAHL

(EBSCO), ProceedingsFirst, and ProQuest Dissertations and Theses. The search included peer-reviewed publications and gray literature, including technical reports, unpublished manuscripts, and dissertations/theses. Gray literature was included to minimize the risk of publication bias.[16] The first publication year selected was 2002, which was the date of the first published study of SST impacts on students; results were limited to English language. The searches were conducted on July 9, 2020. There were 26 × 26 search term pairs used in PubMed, Scopus, and ProQuest. There was no Medical Subject Headings (MeSH) term for "school start time." The first in each pair was one of: middle school*, middle schooler*, junior high*, intermediate school*, lower school*, lower-track secondary school*, 6th grade*, 6th grader*, sixth grade*, sixth grader*, grade 6, grade six, 7th grade*, 7th grader*, seventh grade*, seventh grader*, grade 7, grade seven, 8th grade*, 8th grader*, eighth grade*, eighth grader*, grade 8, grade eight, young adolescent*, young adolescence, WITH the second term of the pair: school start*, "school starting, delay start*, delayed start*, delayed starting, late start*, later start*, later starting, late starting, start time*, starting time*, school hours, late school start*, later school start*, late school starting, later school starting, start time delay*, start time delayed, starting time delay*, starting time delayed, late start school*, late starting school*, later start school*, later starting school*, changing hours, changing school hours. This search yielded a total of 167 articles in PubMed, 265 articles in Scopus, 5 articles in ProceedingsFirst, and 2 articles in ProQuest. The same combined search terms were used in the APA PsycInfo, CINAHL, and ERIC databases, but subject headings from each of the 3 databases were also used as additional search terms. For APA PsycInfo, the headings included "Middle School Students," "Middle School Education," "Middle Schools," "Junior High Schools," and "Junior High School Students." For CINAHL, the headings included "Schools, Middle" and "Students, Middle School." For ERIC, the headings included "Middle Schools," "Grade 6," "Grade 7," "Grade 8," "Middle School Students," "Junior High School Students," "Junior High Schools," "School Schedules," and "Time Factors (Learning)." This search yielded a total of 145 articles in APA PsycInfo, 98 articles in CINAHL, and 454 articles in ERIC. There was a total of 1,136 articles found in all 7 databases.

Screening titles and abstracts

The fourth author screened the initial 1,136 articles and removed 291 duplicates, resulting in 845 articles. To reduce bias and error, 2 independent graduate student reviewers screened article titles and abstracts to determine if the articles met inclusion criteria.[16] Included articles needed: (1) a population that included middle schoolers either identified by grade (ie, 6th–8th) or by age (ie, 11–14 years old), (2) empirical evaluation of either a) the implementation of a change in SST or b) a comparison of schools with different SSTs, and (3) quantitative sleep, behavioral health, or academic outcomes. Articles and abstracts were excluded if they were not empirical with original data (eg, opinions, editorials). The principal investigator instructed reviewers to be over-inclusive in the title and abstract screening review to capture all potential studies for full-text review.[16] Initial screening of titles and abstracts yielded 19 possible articles for full-text review. The reviewers agreed on 58% (n = 11) of the 19 articles. The reviewers disagreed on 8 studies; given the recommendation to be over-inclusive, all possible articles (n = 19) were considered for full-text review.

Before full-text review, the principal investigator examined the 19 articles and found 2 sets of duplicates. Owens et al[17] and Whitaker et al[18] had the same authors and conducted their research in the same location and setting. However, each study differed on the quantitative outcomes measured, thus both studies were used but not collated. Edwards[19] and Edwards[20] had the same author, same location, and same data. Edwards[19] was an editorial, and Edwards[20] was published in a peer-reviewed journal. The reports were collated, and Edwards[20] was used as the primary report. A total of 18 studies advanced to full-text review.

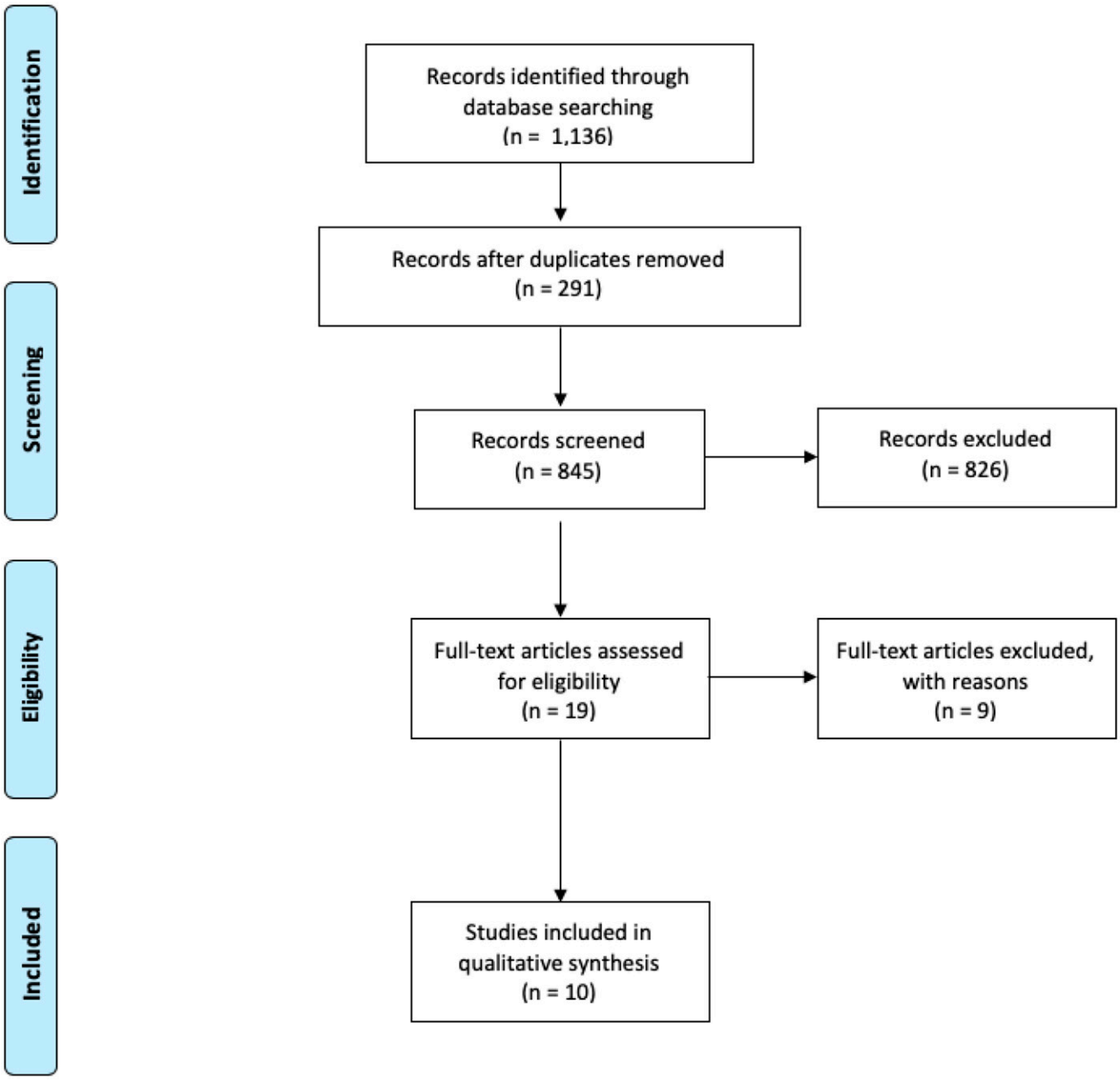
Determining eligibility through full-text review

Inclusion decisions for a narrative review are made based upon the full-text of all eligible studies.[16] The reviewers examined the full-text of the 18 studies to determine whether each study met inclusion criteria. Methodologically, disagreements during this phase are often caused by oversight or differences in interpretation and were resolved by discussion.[16] Of the 18 articles, the reviewers disagreed about 2 studies based on the grade and age criteria, and following discussion, the reviewers and the principal investigator reached consensus to include both because each met the middle school grade criteria. Eight studies were excluded due to: not being empirical ($k = 4$), not being about a change in SST ($k = 2$), not offering quantitative outcomes ($k = 1$), and participants not being in middle school ($k = 1$). Ultimately, 10 studies advanced for narrative synthesis. **Figure 1** presents the process of selecting, screening, and reviewing all articles.

Extraction

Given the review question, extracted data from the 10 articles included details of (1) the location and description of the school(s), (2) student demographics, (3) study design, (4) details regarding the change in SST, (5) measurement of sleep, behavioral health, and academic outcomes, and (6) findings. Sleep outcomes were extracted based upon 5 sleep dimensions[21]: (1) duration, (2) efficiency, (3) timing, (4) daytime sleepiness, and (5) satisfaction. Duration was operationalized as the total amount of sleep obtained in a night, or TST.[21] Efficiency was defined as the ease of falling or returning to sleep and was calculated by dividing TST by time in bed (TIB) and multiplying by 100.[21] The product was a percent, and a higher percentage was interpreted as better sleep efficiency. The National Sleep Foundation recommends a sleep efficiency of at least 85%.[22] Accordingly, it should take a maximum of 30-minutes to fall asleep and a maximum of 20-minutes to get out of bed after the final awakening.[22] For example, if an adolescent goes to bed at 11:00 PM and falls asleep at 11:30 PM, then wakes up at 7:30 AM, and gets out of bed at 7:50 AM, their TIB would be 8.83 hours (ie, the time between 11:00 PM and 7:50 AM) and their TST would be 8 hours (ie, the time between 11:30 PM and 7:30 AM). Eight hours divided by 8.83 hours is 0.906 × 100 = 90.60% sleep efficiency. The adolescent would meet the recommended 85% percentage.[22] Higher efficiency does not mean better sleep quality. For example, if an adolescent

Figure 1—Results of the search, screening, and selection of studies.



goes to bed at 12:00 AM and falls asleep at 12:15 AM, then wakes up and gets out of bed at 6:00 AM, their TIB would be 6 hours (ie, the time between 12:00 AM and 6:00 AM) and their TST would be 5.75 hours (ie, the time between 12:15 AM at 6:00 AM). This adolescent's sleep efficiency would be 95.83% (5.75/6 = 0.9583 × 100); however, the TST of 5.75 hours likely results in insufficient sleep. Timing was defined as the placement of a sleep episode within the 24-hour day, usually benchmarked as bedtime and waketime.[21] Sleepiness is the result of insufficient sleep, or sleep outside the recommended amount of sleep.[23] Students in early adolescence who obtain fewer than 8 hours of sleep or greater than 10 hours of sleep will likely experience daytime sleepiness[23] and difficulty maintaining alertness. Satisfaction was operationalized as the self-reported assessment of sleep quality.[21] The recommended SST is 8:30 AM or later[1]; thus, for this synthesis, schools that started at or after 8:30 AM were considered late, and schools that started before 8:30 AM were considered early. Extracted outcome measures included behavioral health and academic performance, attendance, objective performance measures of cognitive function including measures of sustained attention, inhibition, and executive function, as well as self-reported measures of performance and mood.

RESULTS

Middle school demographic

The 10 studies included were published between 2007 and 2020. Six were conducted in the United States, 2 in Virginia,[17,18] 1 each in North Carolina,[20] Massachusetts,[24] Maryland,[25] and 1 used an archival data set that surveyed various middle schools in the United States.[26] Three studies were conducted in Asia, 1 each in Israel,[27] Singapore,[28] and Korea,[29] and 1 study was conducted in Switzerland.[30] All studies included middle schools, ie, grades 6–8, with the majority sampling 7th- and 8th-grade students. All studies sampled public schools and included suburban and urban areas. The Singapore study was an all-girls school.[28]

The effects of SST and sleep were evaluated in 8 studies.[17,24–30] Five studies examined behavioral health.[18,24,27–29] Three studies evaluated the effect of SST and academic performance.[20,24,26] **Table 1** details demographic characteristics and the quantitative outcomes.

Study designs

The reviewed studies used a variety of designs and methodologies (see **Table 2**). The methods included experimental with control group,[27] prospective, longitudinal within-participants,[28–30] cross-sectional between-participants,[17,18,24,25] and retrospective case-controls.[20,26]

The experimental study[27] randomly assigned 1 class of students (n = 26) to start school at 8:30 AM for 1 week, and the control (n = 21) attended school as usual at 7:30 AM. After 1 week, both groups returned to the usual 7:30 AM time. Data were collected for the experimental week and the following week using actigraphy and sleep diaries. Data analysis compared differences between and within groups.[27]

Three prospective longitudinal studies evaluated SSTs outcomes within the same school population and compared the same students across time. The amount of time instituted for the delay ranged from 20 minutes to 45 minutes with the latest delay being to 9:00 AM,[29] followed by 8:15 AM,[28] and 8:00 AM.[30]

Four cross-sectional studies compared schools or districts with different SSTs. One cross-sectional study compared 2 schools with 7:15 AM and 8:37 AM start times.[24] One study aggregated data from 8 middle schools that began between 7:55 AM and 8:05 AM and compared outcomes to aggregated data from 3 secondary schools that began at either 7:20 AM or 7:25 AM.[25] Two studies compared 2 cohorts of students at the same school after an advance in SST from 8:00 AM to 7:30 AM.[17,18]

Two retrospective case-control studies separated by many years compared outcomes in schools with different SSTs in the same geographical area, one from 1999 to 2006[20] and the other a biannual survey collected in 2008, 2010, and 2012.[26] One study evaluated between-group and within-group differences comparing 32 schools that started at 7:30–7:45 AM and 8:30–8:45 AM and by following a cluster of the same students longitudinally after a delay in start time was implemented.[20] One study compared 8th graders within the same school district across 26 schools with varying SSTs.[26]

Four studies made comparisons of an early-starting school to a late starting school, ranging in times from 8:30 AM to 9:00 AM.[20,24,27,29] Six studies made comparisons of an early school to a school that did not meet the recommended 8:30 AM or later-start time, with comparison schools' start times ranging from 8:00 AM to 8:15 AM.[17,18,25,26,28,30]

Effects of school start times on sleep

Middle schools with late SSTs observed better sleep duration, timing, sleepiness, and satisfaction outcomes than early SSTs. Eight studies offered sleep health outcomes, all of which reported duration.[17,24–30] Two studies computed sleep efficiency,[27,29] 7 studies measured timing of going to bed on school nights,[17,24,25,27–30] 5 studies measured daytime sleepiness,[17,24,25,28,30] and 2 studies measured satisfaction with sleep.[17,29] The sample descriptions, TST, measures of sleep, and sleep outcomes are presented in **Table 1**.

Duration

Schools that made a change in start time to 8:30 AM or later demonstrated benefits in TST. Lufi et al[27] used random design and found that students who were assigned to attend class at 8:30 AM averaged nearly an hour more sleep than peers starting at 7:30 AM. Kim et al[29] used a within-participants study and followed a single cohort that experienced a delay in the SST to 9:00 AM and collected data 2 months and 12 months after the delay. Data were not collected before implementing the delay, thus change data were unavailable; nonetheless, students reported achieving 8.1 hours of sleep at the 2-month and 7.3 hours of sleep at the 12-month data collections. Taken together, middle school students obtained at least the 8 hours of recommended sleep when middle schools started at 8:30 AM or later.

When SST shifts were to 8:30 AM or earlier, there was less improvement in TST. Two studies used prospective longitudinal designs and followed the same cohort across a school start delay to 8:15 AM and 8:00 AM. Lo et al[28] compared TST changes in an all-girls school in Singapore after implementing a new start time of 8:15 AM. After 1 month, students' actigraphy data suggested a longer TST of 2.06 minutes and a statistically significant increase of 9.95 minutes at 9-month follow-up. Although there was an improvement in TST following this 45-minute delay, the sample was still sleep-deprived, averaging 5 hours and 48 minutes sleep on school nights, and all students reported fewer than 7 hours of sleep across every time point.[28] Das-Friebel et al[30] compared TST after a delayed start time to 8:00 AM was implemented at a Switzerland school and did not observe a significant change in sleep; after the delay, students self-reported 8 hours and 2 minutes of sleep.[30]

Cross-sectional comparisons found that students attending later-starting schools had more TST than students attending earlier-starting schools. Four studies used cross-sectional methods to compare middle schools with different start times.[17,24–26] In Wolfson et al's[24] study, students who started at 8:37 AM reported 37 minutes more TST during the Fall semester (M = 8.90 hours) and 65 minutes more TST during the Spring semester (M = 8.92 hours) than students who started at 7:15 AM. Students who started at 7:15 AM obtained 8.28 hours of sleep in the Fall semester and 7.83 hours of sleep in the Spring semester; comparatively, students who attended the 8:37 AM starting school consistently obtained almost 9 hours of sleep across both

Table 1—Student and school demographics and sleep, behavioral health, and academic performance outcomes.

Author, Year, Country	Type of School	Sample (mean age, age range, percent girls, percent students of color)	Total Sleep Time (TST)	Sleep Measure	Duration	Efficiency	Timing	Alertness and Sleepiness	Satisfaction/ Quality	Behavioral Health	Academic
Lufi et al, 2011[27] Israel	Public (8th-graders)	*N* = 47, M_{age} = 13.78 (SD = 0.28), 57% girls	Experimental: 8 hours, 26 min. (week 1) and 7 hours, 31 min. (week 2) Control: 7 hours and 29 min. (week 1) and 7 hours, 18 min. (week 2)	Actigraphy and daily sleep logs for 5-day period	✓	✓	✓			Executive function (MATH-CPT, d2 Task of Inattention)	
Owens et al,[17] 2017 USA	10th largest US school district; 19 public schools (3 secondary, 8 middle schools)	*N* = 1,051, M_{age} = 13.5 (SD = 0.60), 54.6% girls, 44.1% students of color, 64% FRL	Before SST advance: 8 hours and 25 min.; after SST advance: 8 hours and 9 min.	SSHS, Sleepiness subscale	✓		✓	✓	✓		
Temkin et al,[25] 2018 USA	8 middle schools (7th/8th grade) and 3 secondary school (7th–12th grade) from a "diverse suburban school district"	*N* = 973, age range 12–15, 51% girls, 38% students of color, 5% FRL	Early SST: 8.15 hours, later SST: 8.39 hours	School Sleep Habits Survey, Sleepiness subscale; PSQI	✓		✓	✓			
Lo et al, 2018[28] Singapore	All-girls' secondary school (7th–12th)	*N* = 375, M_{ag} = 14.6 (SD = 1.15), 1-month f/up (n = 352), 9-month f/up (n = 150)	1-month: 2.06 min. increase, 9-month: 9.95 min. increase; both time points: average TST was 5 hours and 48 min.	Actigraphy, daily sleep logs; Karolinska Sleepiness Scale	✓		✓	✓		PANAS-X	
Das-Friebel et al,[30] 2020 Switzerland	3 Lower-track secondary schools (8th–9th grade)	School Start Time Change group (n = 249), M_{age} = 14.82 (.54), 41.8% female; comparison group (n = 414), M_{age}=14.97 [.60], 47.3% female	T1: 8 hours, 10 min. T2: 8 hours, 2 min.	Student school satisfaction survey	✓		✓	✓			
Wolfson et al,[24] 2007 USA	Urban public	*N* = 205, 7th (n = 99), 8th-graders (n = 106), 60% girls, 18% FRL, 40% students of color (school L), 54% students of color (school E)	School L Fall: 8.90 hours, Spring: 8.92 hours; school E Fall: 8.28 hours, Spring 7.83 hours	SSHS, Sleepiness and Sleep-Wake Behavior Problems subscales	✓		✓	✓		Attendance and tardiness records	Fall term GPA (100-point scale)

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Table 1—Student and school demographics and sleep, behavioral health, and academic performance outcomes. (*Continued*)

Author, Year, Country	Type of School	Sample (mean age, age range, percent girls, percent students of color)	Total Sleep Time (TST)	Sleep Measure	Duration	Efficiency	Timing	Alertness and Sleepiness	Satisfaction/ Quality	Behavioral Health	Academic
Kim et al, 2019[29] Korea	Public	*N* = 238, M_{age} = 13.5(*SD* = 0.5), range 13–14, 54.62% girls	Increase TST: 2-month: 7.4 hours; 12-month: 8.0 hours; decrease TST: 2-month 8.1 hours, 12-month: 7.3 hours	PSQI; SSHS, Sleepiness and Sleep/ Wake Problem Behavior subscale	✓	✓	✓	✓	✓	PANAS-X, Depressed Mood subscale, self-reported tardiness	
Lewin et al, 2017[26] United States	26 "demographically diverse school districts"	*N* = 6,936 (Year 2008), n = 11,991 (Year 2010), n = 10,768 (Year 2012), 58.2% students of color, 50.2% girls, 58% of schools ranged from 25%–75% eligibility for FRL	Earliest: less likely to report less than 8 hours of TST compared to "latest"	Weeknight sleep duration (< 7 hours, 7 hours, 8 hours, or > 9 hours)	✓						Self-reported grades and academic effort
Whitaker et al,[18] 2019 United States	10th largest US school district, 19 public schools (3 secondary, 8 middle schools)	*N* = 1,051, 7th- and 8th-grade students, M_{age} = 13.5 (SD = 0.60) years, 54.6% girls, 44.1% students of color, 64% FRL	Before SST advance: 8 hours and 25 min. After SST advance: 8 hours and 9 min.							Executive function (BRIEF), self-reported injury, physical activity, and BMI	
Edwards, 2012[20] USA	16th largest district, mostly urban/ suburban		Did not report								End-of-grade test scores

✓ = measured outcome, BMI = body mass index, FRL = free/reduced lunch, M_{age} = median age, MATH-CPT = Mathematics Continuous Performance Test, PANAS = Positive and Negative Affect Schedule, PSQI = Pittsburgh Subjective Sleep Quality Index, SD = standard deviation, SST = school start time, TST = total sleep time.

Table 2—Study methodology among middle schools with later start time (n = 10).

Author	Study Description and Sampling	DST	Amount of Shift (min)	Longitudinal (within)	Cross-Sectional (between)	Length of Data Collection	Methodology
Lufi et al[27]	*Design*: Experimental, posttest only control design *Sampling*: Random assignment to experimental group (n = 26) and control (n = 21)	8:30	60	Experimental group compared within participant from week 1 (began at 8:30 AM) to week 2 (began at 7:30 AM)	Experimental group compared between participants with control group at week 1 and week 2	2-week span, 5 days for each week (Saturday night–Thursday morning)	One class was randomly assigned to start school at 8:30 AM during week 1 and resume at 7:30 AM week 2. One class was randomly assigned to start class at 7:30 AM both weeks. All participants wore an actigraph and completed sleep diaries for 2 weeks.
Das-Friebel et al[30]	*Design*: Cross-sequential *Sampling*: Convenience	8:00	20	Two different cohorts at 3 different schools experienced a DST and were compared before and after the DST	Between participants: One cohort did not experience a DST and were compared to the 2 cohorts that did experience a DST	Before and after DST across 2013–14 and 2015–16 academic years	Data were collected twice, once before the DST and once after the DST at the end of each academic year for 2 different cohorts, including academic year 2013–14 to 2014–15 and 2014–15 to 2015–16.
Edwards[20]	*Design*: Retrospective historical cross-sequential *Sampling*: Archival	8:30	60	Compared same students who made shift from 7:30 AM to 8:30 AM	Compared schools with start times ranging from 7:30 AM or 8:30 AM	1999 to 2006	Data were collected for every student in NC between 1999 and 2006 and included SST and state reading and math scores. Data was analyzed cross-sectionally and longitudinally across time.
Lo et al[28]	*Design*: Prospective longitudina *Sampling*: Convenience	8:15	45	The same cohort of students were compared before DST, 1-month DST, and 9-month DST		Baseline (April 2016), 1-month follow-up (August 2016) and 9-month follow-up (April 2017)	Data were collected during a period of 1 month per phase data collection phase. Students completed online surveys and wore wrist actigraph for 1 week during each data collection phase.
Kim et al[29]	*Design*: Prospective longitudinal *Sampling*: Observational	9:00	40	The same cohort of students were compared 2-month after DST and 12-months after DST		November 2014 (2-month follow-up) and September 2015 (12-month follow-up)	Students completed questionnaires at each time point after DST. Researchers divided students into 2 groups based on whether TST increased or decreased from 2 month to 12 months. Researchers compared outcomes between the 2 different groups across time.
Wolfson et al[24]	*Design*: Cross-sectional *Sampling*: Random cluster selection	x	x		Compared early-starting school E (7:15 AM) to late-starting school L (8:37 AM)	Fall 2003 and Spring 2004	School L and school E were from the same school district. Students at each school completed questionnaires at each data collection time point. Comparisons were made between groups across both time periods.
Owens et al*[17]	*Design*: Repeated cross-sectional *Sampling*: Convenience	x	x		Compared 2 different cohorts of students at the same school that advanced start time 8:00 AM to 7:30 AM	March 2015–June 2015 compared to March 2016–June 2016	Students completed online surveys during the Spring term before the start time advance and after the start time advance.

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Table 2—Study methodology among middle schools with later start time (n = 10). (*Continued*)

Author	Study Description and Sampling	DST	Amount of Shift (min)	Longitudinal (within)	Cross-Sectional (between)	Length of Data Collection	Methodology
Lewin et al[26]	*Design*: Retrospective case-control *Sampling*: Convenience	x	x		Compared 3 different SST: "earliest" (7:20–7:30), "early" (7:40–7:55), and "latest" (8:00–8:10).	2008, 2010, 2012 annual survey	Data was collected from a publicly available data set. Survey responses were analyzed across 3 different years for 8th graders with various school start times.
Temkin et al[25]	*Design*: Cross-sectional *Sampling*: Convenience	x	x		Compared later SST (7:55–8:05 AM for 7–8th) and earlier SST (7:20–7:25 AM for 7th–12th).	Spring 2015	Students completed online surveys and school records were obtained during the Spring 2015 term. Comparisons were made across different schools with "later" or "earlier" start times
Whitaker et al[18]	*Design*: Repeated cross-sectional *Sampling*: Convenience	x	x		Compared 2 different cohorts of students at the same school that advanced start time 8:00 AM to 7:30 AM	March 2015–June 2015 compared to March 2016–June 2016	Students completed online surveys during the Spring term before the start time advance and after the start time advance.

DST = delay start time, NC = North Carolina, SST = school start time, x = did not delay SST.

semesters.[24] Temkin et al[25] found that students attending schools starting at 7:55 AM to 8:05 AM averaged 8.25–8.39 hours of sleep on school nights, compared to students attending 7:20 AM to 7:30 AM starting schools who average 8.15 hours of sleep on school nights.[25]

One study examined an advanced start time, in other words, a school that shifted SST to even earlier. Owens et al[17] compared 2 cohorts at the same school that advanced from 8:00 AM to 7:30 AM; students self-reported a reduction in school-night TST, from 8 hours and 25 minutes to 8 hours and 9 minutes. Lewin et al[26] found that students attending schools that started between 7:20 AM to 7:55 AM were more likely to report fewer than 8 hours of TST on school nights compared to students attending schools that started between 8:00 AM to 8:10 AM, who obtained more than 8 hours of TST. Aggregating across these 4 studies, there is a consistent observation that late SSTs are associated with more sleep, while 7:30 AM or earlier SSTs are associated with middle schoolers obtaining insufficient sleep.

Efficiency

Studies that used between- and within-participants designs found that sleep efficiency did not change after SST delays. Two studies measured sleep efficiency.[27,29] Lufi et al[27] used actigraphy to calculate sleep efficiency. There were no significant between-group differences in sleep efficiency after the first week of the experiment, such that the experimental group earned a 95.72% sleep efficiency, and the control group earned a 92.43% sleep efficiency.[27] Students in the control condition reported 7.29 hours of sleep.[27] Kim et al[29] found students' sleep efficiency was at least 87% across all time points, regardless of students' TST increasing or decreasing after a start time change to 9:00 AM. Students averaged 7.7 hours of sleep on school nights.[29] Both studies observed that students achieved the recommended threshold of sleep efficiency but did not achieve the recommended 8 hours of sleep for adolescents.[27,29]

Timing

Students attending late-starting schools generally reported delayed waketimes. Seven studies measured sleep timing on a school night.[17,24,25,27–30] Four studies evaluated longitudinal differences in timing after SST delay. In their experiment, Lufi and colleagues[27] found that students assigned to the 8:30 AM SST woke up significantly later (approximately 7:07 AM), compared to students assigned to 7:30 AM (approximately 6:27 AM). Notably, students in both conditions were instructed to "[go] to bed at their regular time; to ensure that they gained an extra hour of sleep."[(p139)] Students in the experimental late-SST group went to bed 17 minutes earlier than the control group.[27] Three studies compared TIB on school days before and after a start time delay.[28–30] Das-Friebel et al[30] compared changes in self-reported TIB after a 20-minute delay to 8:00 AM. There was a null change in TIB after the delay; bedtime was delayed by 25 minutes and waketime was delayed by 18 minutes, resulting in a nonsignificant change of 7 minutes.[30] In Lo et al's[28] study, students self-reported their TIB following the first month after an 8:15 AM start time delay. Students reported a significant delay in bedtime by 8.98 minutes and a significant delay in waketime by 31.61 minutes.[28] These gains were maintained at

the 9-month follow-up, such that students reported significantly more TIB due to a more robust delay in waketime than bedtime.[28] Finally, Kim et al[29] found that students who reported a longer TST following a shift to 9:00 AM also reported a significant delay in waketime without significant changes in bedtime at the 12-month follow-up.

Cross-sectional comparisons found that late SSTs were associated with youth delaying waketimes. Three studies used cross-sectional designs to compare early and late starting schools.[17,24,25] Wolfson et al[24] found that during the Fall semester, students who attended a school with an 8:37 AM SST went to bed 22 minutes later than students who attended a 7:15 AM starting school; however, late-starters woke up 75 minutes later than early-starters. During the Spring semester, there were no significant differences in bedtime across early-start and late-start middle schoolers; however, late-starters reported waking up 65 minutes later than early-starters.[24] Temkin et al[25] found that students who attended middle schools starting between 7:20 AM and 7:25 AM were significantly more likely to go to bed 15 minutes earlier (M = 9:43 PM), compared to students attending schools that started between 7:55 AM and 8:05 AM. Although not statistically significant, students who attended the later-starting schools woke up an average of 33 minutes later than students at the earlier starting schools.[25] After a 30-minute advance in start time to 7:30 AM, Owens et al[17] found that students reported a significantly earlier bedtime and waketime, by 9 minutes and 25 minutes respectively, meaning that a 30-minute advance in SST resulted in an average 16 minutes of sleep loss.

Sleepiness

The 5 studies[17,24,25,28,30] that evaluated SSTs and daytime sleepiness provided consistent findings that middle schools that started before 8:00 AM were associated with more daytime sleepiness. In Wolfson et al's[24] study, students attending a late-starting school had less daytime sleepiness than students attending an early-starting school. Using the Sleepiness subscale of the Sleep Habits Questionnaire, middle schoolers self-reported daytime sleepiness in the preceding 2 weeks. Students who attended the 8:37 AM starting school reported significantly less daytime sleepiness than students who attended the 7:30 AM starting school.[24] Similarly, Lo et al[28] found students self-reported a statistically significant improvement in daytime sleepiness after 1 month and 9 months following an 8:15 AM delay in SST. In Das-Friebel et al's[30] study, students did not self-report a change in daytime sleepiness after a 15-minute delayed start time to 8:00 AM. Temkin et al[25] also used the Sleepiness subscale of the Sleep Habits Questionnaires and found that students who started school between 7:55 AM and 8:00 AM were less likely to report daytime sleepiness and more likely to report feeling wide awake than students who attended schools starting before 7:25 AM. Moreover, they found that 8th-grade students and middle school girls who attended schools that started between 7:55 AM and 8:05 AM were more likely to report daytime sleepiness than 7th-grade students and middle school boys.[25] In Owens et al's[17] study, students self-reported a significant increase in daytime sleepiness after an advance in SST to 7:30 AM; 57.2% of students reported daytime sleepiness before the advance and 65.6% reported daytime sleepiness after the advance. Moreover, after the advance, there was a 3.1% increase in students who reported napping on school days.[17] Wolfson et al[24] evaluated sleep-wake behavior problems using the Sleep-Wake Behavioral Problems subscale on the Sleep Habits Questionnaires, which asked students to report the frequency of erratic sleep-wake behaviors in the previous 2 weeks. Students who attended the 8:37 AM starting school reported less sleep-wake behavior problems than did students attending the 7:15 AM starting school during the Fall and Spring semesters.[24]

Satisfaction

Early SSTs were associated with poorer sleep satisfaction, and later SSTs contributed to healthier sleep quality. Two studies examined whether delayed SSTs positively impacted satisfaction with sleep[17] and self-reported sleep quality.[29] Owens et al[17] asked students about their sleep satisfaction in the preceding 2 weeks and created a binary code for sleep satisfaction; students who reported being satisfied "never," "once," or "twice" were coded as dissatisfied and students who reported "several times" or "every day/night" were coded as satisfied. Following the 30-minute advance to 7:30 AM, there was a significant increase in sleep dissatisfaction; 50.1% of students reported being dissatisfied after the advance compared to the 41% of students before the advance.[17] Kim et al[29] used the Pittsburgh Subjective Sleep Quality Index (PSQI) to measure sleep quality. After a 40-minute delay in start time to 9:00 AM, there was no significant change in PSQI self-reported sleep quality at the 2-month or 12-month follow-up; however, pre-delay scores were already in a healthy range with little to no room for improvement.[29]

Effects of school start times on behavioral health

The relationship of SSTs to behavioral health was evaluated in 5 studies.[18,24,27–29] Of these 5 studies, 2 measured attendance, indexed by tardiness and absences,[24,29] 2 measured cognitive ability, including attention[27] and emotion regulation,[18] 2 evaluated changes in affect and mood,[28,29] and 1 study evaluated physical health and injury.[18]

Tardiness and absences

Middle schools that instituted a delay in SST to at least 8:30 AM observed improvements in tardiness and absences. Kim et al's[29] longitudinal study compared students' self-reported tardiness after a 40-minute delay to 9:00 AM. Students were asked, "*How many times were you tardy at school per week*?" at 2 months and 12 months following the delay. There was a significant reduction in tardiness at 2 months, and this decline remained low at the 12th-month follow-up ($M_{days\ tardy}$ = 1.10).[29] Wolfson et al's[24] cross-sectional study compared 7th- and 8th-graders and found that tardiness was significantly higher for both grades of students at the early-start school, 7:15 AM compared to those at the 8:37 AM starting school. Specifically, 7th-graders at the early-start school had 3.5 times more tardiness than students at the late-starting school; 8th-graders at the early-starting school had 5.5 times more tardiness than late-starters.[24] There were no significant differences in absences across grades.[24]

Cognitive abilities

Students who report more TST exhibited better performance on tasks that measured executive function. Lufi et al[27] used 2 standardized tests, the Mathematics Continuous Performance Test and d2 Test of Attention (Hogrefe Publishing Corp., Newburyport, MA), to measure changes in students' sustained attention and impulsivity and researchers randomly assigning students to 1 of 2 SST conditions. Students assigned to the 8:30 AM start time performed significantly better on a sustained attention task than students who started at 7:30 AM. Additionally, students starting at 8:30 AM responded less impulsively and made fewer errors on the d2 Test of Attention than earlier starters.[27] Whitaker et al[18] used the Behavior Rating Inventory of Executive Function (Par, Lutz, FL) to examine changes in self-regulation following a 30-minute advance in SST, from 8:00 AM to 7:30 AM. Students' self-reported regulation did not change after the start time advance, although self-regulation scores declined.[18]

Affect and mood

Late SSTs also improved middle schoolers' moods. Two longitudinal studies[28,29] used the Positive Affect and Negative Affect Schedule to measure perceived affect. In Kim et al's[29] study, after an increase in opportunity for sleep due to a later SST shift, all students improved in negative affect, which included less fear, hostility, guilt, and sadness. Interestingly, Kim et al found that the improvement was independent of students' reports about whether they had more TST after the 40-minute delay to 9:00 AM.[29] In Lo et al's[28] study, students who achieved more sleep reported a significant reduction in negative affect at 1-month and 9-month follow-up after a 45-minute shift to 8:15 AM.[28]

Late SSTs improved mood-related concerns, including self-reported depression and anxiety. Kim et al[29] found that students who experienced a delay in SST reported lower depressive symptoms and perceived stress, and less engagement in behavioral and verbal aggressive actions at the 12-month follow-up. Lo et al[28] reported similar findings; students self-reported a decrease in depressive symptoms at 1-month and 9-month follow-up.[28]

Health behaviors and injury

One study examined injury in relation to SST.[18] Whitaker et al[18] aggregated data from 8 middle schools. One cohort of 7th- to 8th-graders (n = 601) before the SST advance was compared to a different cohort of 7th- to 8th-graders (n = 450) after the advance to a 7:30 AM SST. Following the advance, there were no significant changes in fair/poor self-reported health, physical activity, body mass index > 85th percentile, sport or exercise injuries, or other injuries queried in the prior 6 months.[18]

Effects of school start times on academic performance

Middle schools that instituted an 8:30 AM or later SST observed improvements in academic performance. Three studies evaluated the effect of SSTs on academic performance.[20,24,26] Among these studies, the new SSTs varied from 8:10 AM to 8:37 AM. The methods for collecting academic performance data varied. One cross-sectional study used Fall-term GPA based on English, math, science, and social studies grades.[24] One study used archival data of standardized test scores for reading and math.[20] One study used self-reported grades, asking participants, "*Do you mainly get As, Bs, Cs, Ds, or Fs?*" and "*How often did you not finish your homework?*"[26]

In cross-sectional and longitudinal comparisons of standardized test scores in reading and math among middle schools that delayed their start time by 60-minutes to 8:30 AM,[20] students earned higher math and reading standardized test scores by about 3% points after the delay. Edwards'[20] longitudinally examined test scores for students who remained in the same school and found that students who attended the 8:30 AM SST evidenced a 1.8%-point increase in math scores and a 1.0%-point increase in reading scores. Improvements were not independent of age. Eleven and 12-year-olds scored about the same on reading and math regardless of SST. However, 13- and 14-year-olds attending an 8:30 AM starting school had significantly higher math and reading scores than 11- and 12-year-olds.[20] Using a cross-sectional design, Wolfson et al[24] found that 8th-graders who attended the 8:37 AM starting school earned a higher GPA (M = 83.79%) than 8th-graders who attended the 7:15 AM starting school (M_{GPA} = 76.85%), a letter grade difference. Notably, there were no significant GPA differences between 7th-graders at schools with different start times.[24] Lewin et al[26] used a cross-sectional design and compared self-reported grade and homework completion among schools with various SSTs.[26] The probability of getting As were highest for students who slept 8 hours and lowest for those who slept fewer than 7 hours. Students attending 7:20 AM and 7:55 AM SSTs reported worse grades compared to later-starting schools. Of note, 90% of the sample reported earning mostly As and Bs. Students who attended 7:40 AM to 7:55 AM schools were more likely to report not completing their homework than students attending 8:00 AM to 8:10 AM schools.[26]

DISCUSSION

The purpose of this narrative review was to aggregate outcomes of SSTs for studies with middle schoolers. To our knowledge, this is the first synthesis of the SST literature that interprets sleep, behavioral health, and academic performance among middle schools that have delayed SST or compared early and late SSTs. Decades of empirical evidence suggest that high schoolers benefit from late SSTs, particularly when schools begin at 8:30 AM or later.[6–9] Little research has examined middle schoolers and SSTs. Given that the recommended amount of sleep increases from later childhood to adolescence, and that middle school occurs during the onset of puberty,[15] it may be that the SST literature on high schoolers would generalize to middle schoolers. The current narrative review sought to synthesize the literature on SST and middle school in order to determine whether late SST would benefit this age group.

8:30 AM or later SSTs are associated with the best outcomes

The results of the narrative review demonstrated that middle schools that started at 8:30 AM or later evidenced improvements

in sleep, behavioral health, and academic performance. Middle school students who attended late starting schools demonstrated longer sleep durations,[24,27,29] higher sleep efficiency,[27,29] longer TST,[24,27,29] less daytime sleepiness,[24] and healthier sleep quality.[29] Of the studies that examined changes in sleep duration for late-starting schools, students not only obtained at least 37 more minutes of sleep on school nights but were also able to satisfy the minimum 8 hours of recommended sleep for adolescents.[24,27,29] Consistent with the high school literature on late SSTs, changes in waketime explained the improvement in TST for late-starters. With an 8:30 AM or later SST, middle school students had more TIB and obtained more sleep due to a delayed waketime.[24,27,29] Although 2 researchers found adolescents delayed their bedtime, this delay was negligible when compared to the delay in waketime.[24,27] Late SSTs are associated with a healthy sleep efficiency score of at least 85%.[27,29] Students attending late-starting schools reported less daytime sleepiness and sleep-wake behavior problems[24] and healthy sleep quality on school days.[29] Improvements in sleep and alertness may be a mechanism to promote engagement in school, such that students may be less likely to nap at school or doze off during instruction.

Middle schools that started at 8:30 AM or later were not only associated with better sleep outcomes, but several secondary benefits were observed. Late SST was associated with better behavioral health and academic performance including less tardiness,[24,29] better cognitive abilities,[27] improved affect and mood,[29] and higher performance on standardized tests[20] and better GPAs.[24] Late SSTs results in fewer self-reported and objective tardiness rates.[24,29] Our findings of late SSTs and absences were not consistent with the high school literature that had found late SSTs were associated with significant improvement in attendance.[7,9] To our knowledge, no studies have cross-sequentially evaluated changes in absences rates like the high school literature. The single study that evaluated executive function using objective and psychometrically validated measures found that an 8:30 AM SST improved students' attention and impulsivity.[27] Sleep impacted executive function[27]; however, the extent to which SSTs may have interacted with sleep and executive function was less clear. It could be that more sleep, and consequently less daytime sleepiness, positively impacted students' abilities to sustain attention and inhibit responses. The opportunity to obtain the recommended 8 hours of sleep with an 8:30 AM SST may position middle school students to attend to classroom instruction and engage in healthy decision-making.[1]

More TST, achieved by students at late-starting schools, results in improved proximal and distal depressive symptoms, perceived stress, and less engagement in behavioral and verbal aggressive actions.[29] A delay in SST to 9:00 AM, the latest absolute SST reviewed in this synthesis, improved students' depressive symptoms a month after the delay and this improvement was sustained to the end of the school year.[29] Additionally, students' perceived stress and engagement in behavioral and verbal aggressive actions improved after the delay.[29]

Both studies that sampled students from a late-starting school found students had higher GPA[24] and improved standardized test scores,[20] particularly for older middle school students such as those in the 8th grade. It could be that younger middle schoolers have not yet reached puberty and therefore may not benefit from the opportunity for more morning sleep that accompanies a shift in pubertal circadian rhythms; therefore, secondary outcomes like improved GPA and standardized test scores may not occur for these younger students. Taken together, it appears that 8:30 AM SST plays an important role in positively impacting school attendance, learning, mental health, and academic performance.

Early SSTs are associated with the worst outcomes

This narrative review suggests that early middle school start times are associated with worse sleep, behavioral health, and academic performance outcomes. Middle school students attending early-starting schools of 8:00 AM or earlier were less likely to obtain the recommended 8 hours of TST on school nights[25] and reported lower TST.[17] Moreover, early starting schools were associated with students' early rise times.[17] The single study that advanced SST to 7:30 AM found that students reported greater dissatisfaction in their sleep quality, had more daytime sleepiness, and higher incidences of napping after the advance.[17]

Wolfson et al[24] found that 7th- and 8th- grade students were 3.5–5.5 times more likely to be tardy at the early-starting school than late starting school, even after controlling for school size, ethnic distribution, and socioeconomic status. The single study that examined healthy behaviors and injury after an advance in SST did not yield statistically significant findings. Both the original start time and the advanced start time were earlier than the recommended 8:30 AM start time, thus results are inconclusive as to whether schools' late-starts impact physical health and injury rates. Early middle SSTs are associated with lower self-regulation,[17] worse self-reported grades, and homework incompletion.[26] Taken together, the results of the current narrative review evidence that early SSTs negatively impact middle schoolers' sleep, and have negative implications for students' learning, mood, and academic performance.

Relative benefits of delays in SST

Although it is clear that an absolute start time of 8:30 AM or earlier is ideal for middle schoolers, the results of this narrative review show when schools delay start times even small amounts, middle schoolers benefit. Two middle schools delayed SST by 20 minutes or more, but the absolute start time remained earlier than recommended[1]; both found that students successfully obtained at least 8 hours of sleep after the delay.[28,30] The students evidenced small shifts in bedtime and waketime, which likely explains the small increase in TST after the delay.[28,30] Students attending an 8:15 AM starting school reported improved daytime sleepiness and more wakefulness after a delay.[28] Finally, middle school students attending an 8:15 AM starting school reported less negative affect and fewer depressive symptoms after a delay.[28]

Overall, the 2 longitudinal studies that implemented a delay earlier than 8:30 AM found small gains that were not statistically significant improvements.[28,30] Though the actual SSTs not being 8:30 AM may explain the modest findings, it is also possible that cultural differences may have contributed to these

findings since 1 study was at an all-girls school in Singapore and the other study was in Switzerland. Compared to the United States, students in Singapore attend more days of school and have fewer days off during the year.[31] In the Singapore study, students were especially sleep deprived, averaging fewer than 6 hours of nightly sleep. Cultural differences in the demands and expectations for academic performance and sleep expectations may explain differences.[31]

Limitations of the narrative review

Although there is compelling evidence that 8:30 AM or later SSTs positively impact sleep, behavioral health, and academic performance, it is also important to acknowledge salient methodological limitations across the reviewed studies when interpreting findings.

Cohort effects

Half of the reviewed studies used a cross-sectional design; researchers made comparisons between different groups at a given time point. Researchers were not able to make causal inferences that a change in start time contributed to findings; rather, a difference in SST contributed to differences in outcomes. There may be cohort effects between comparison groups and group differences across student cohorts and schools, which may have confounded the results.[32] While some studies noted demographic similarities between groups[17,20,24,26,30] and controlled for differences, other studies either did not report or control for cohort effects.[27,28]

Floor effects

The interpretation of findings may have been limited by the lower range of scores on measures.[32] For example, Kim et al[29] evaluated longitudinal differences in sleep quality after implementing an 9:00 AM SST. Self-reported sleep quality was in the healthy range at the 8:20 AM pre-delay SST, 10 minutes shy of the 8:30 AM recommendation.[1,29] A floor effect may explain the lack of change in low sleep quality score, such that it was already in a healthy range. A floor effect may also confound interpretation for tardiness rates; although Kim et al[29] observed a significant reduction in tardiness after the delay, there was already a low pre-delay tardiness rate before the delay.

Hawthorne effect

Lufi et al[27] offered the most methodologically robust study design. They used random assignment, which controlled for selection bias, and allowed for stronger inferences supporting an 8:30 AM start time due to improved proximal sleep outcomes. They found robust differences in TST between groups after implementing the delay; however, it is difficult to infer whether students would have changed their bedtime if the researchers had not instructed them to keep it the same. A Hawthorne effect[33] could have impacted outcomes. Students in the experimental group knew they were being observed on sleep measures; consequently, they might have altered their behavior to obtain more sleep by going to bed earlier and waking up later or may simply have perceived an improvement because it was expected.

Measurement validity

The 2 studies that measured sleep efficiency observed that their sample of students met the recommended sleep efficiency score of 85% after a delay to at least 8:30 AM.[27,29] Notably, students across both samples did not meet the recommended 8 hours of sleep per night. The high sleep efficiency but subsequent low TST may be an indicator of sleep deprivation. Sleep efficiency of 91% or higher has been shown to indicate sleep deprivation.[34] The insufficient sleep from these 2 samples may confound the interpretation of sleep efficiency. The students may have maximized their time to sleep, but they were not obtaining enough sleep. In other words, students had high sleep efficiency, but this did not accurately index healthy sleep. As such, the findings for the relationship between late SSTs and sleep efficiency should be interpreted with caution.

Sampling

The sampling characteristics of the reviewed studies offered a wide range of student and school demographics. Notably, not every article included participants within the accurate parameters of middle school grade or age. For example, some studies included participants who were in the 9th grade,[28,30] or were older than 14-years-old,[25,28,30] or restricted by sex.[28] These factors may confound results, such that age or sex could conflate findings. Moreover, the studies offered a diverse population of students, such that 4 of the 10 studies were conducted in countries outside of the United States. It may be more challenging to generalize sleep, behavioral health, and academic performance following a SST change, considering cultural differences in educational performance and sleep expectations across counties. That said, the diversity of the reviewed studies cannot be overstated. The synthesis offers support that a later SST aligns with the biological shift in circadian rhythms across continents and cultures.

Timing of measurement

The timing of data collection affects external validity for some studies. In Lufi et al's[27] experiment, students in the experimental group were only given a week of the manipulation to experience the delayed SST. A week may only minimally impact sleep timing and duration, as it typically takes up to 2 weeks to adjust to a new sleep schedule.[35] Therefore, it is difficult to infer whether students had enough time to adjust their sleep and obtain the maximum benefit in an 8:30 AM SST. Additionally, Kim et al[29] used a longitudinal study design but did not collect pre-SST data. Therefore, it is difficult to infer whether the delay in SST changed sleep and behavioral health without knowing baseline scores.

CONCLUSIONS

We recommend that future research build on the existing literature of middle school start times, specifically evaluating behavioral health and academic performance. Most of the articles included in

this review were published in medical journals. To support efforts for future reviews and replication, we recommend that "school start time" be added as a descriptor in the Medical Subject Headings database. To our knowledge, no studies have evaluated physical health outcomes (eg, sports injuries or obesity) following a middle school start time delay. Moreover, prospective longitudinal studies, experimental, and cross-sequential designs, are needed to make stronger inferences about the nature and impact of late SSTs for middle schoolers.

Given the different ages of puberty onset in middle school, it may be especially important for future researchers to document and evaluate the interactions of grade, age, and sex related to SST. Temkin et al[25] found a sex-by-grade difference for daytime sleepiness, such that girls and 8th-graders were more likely to report daytime sleepiness than were boys and 7th-graders. Moreover, both Edwards[20] and Wolfson et al[24] found age differences in academic performance between 7th- and 8th-grade students, such that older students demonstrated greater gains on standardized tests than younger students. We recommend that future researchers evaluate how these constructs account for differences in outcomes.

An important observation from this narrative review is that late middle school start times were not associated with iatrogenic effects. Furthermore, there was a robust finding that 8:30 AM or later-starting middle schools had the best outcomes for optimal sleep and were associated with the greatest improvements in behavioral health and academic performance. Given the current and active status of the SST movement, science-informed research is needed to build a strong evidence base that can inform public policy to promote late middle school start times.

ABBREVIATIONS

GPA, grade point average
SST, school start time
TIB, time in bed
TST, total sleep time

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DISCLOSURE STATEMENT

All authors have seen and approved this submission. The authors report no conflicts of interest.