Shrewsbury Public Schools
Sleep Health Advisory Committee

Report from the Research Task Group

Review of Literature and Recent Data
Assessing the Impact of Delayed School Start Times on
Student Health, Safety, and Academic Performance

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Research Task Group members:

Kristen Ditch
- PharmD
- BCCCP

Jennifer Giampapa
- Certified Health Coach

Michael C. Cerio
- M.B.A. Columbia University, Strategy & Operations
- M.S. Biochemistry & Molecular Biology, University of Connecticut
- B.S. Syracuse University, Biology
- 20 years' experience in biotechnology, oncology R&D, study design, data analytics

Toral Parikh, M.D.
- Family Medicine and Urgent Care Physician

Cynthia J. Murphy
- A.B.D., UMass Lowell, College of Education
- M.A., Trinity College, English & Creative Writing
- Associate Professor of English, Goodwin University, 20 years
- UDL Teaching Fellow

Laura Braun-Lush
- M.A., S.S.P.
- Licensed School Psychologist

Rishi Vohora, D.O.
- Cardiologist

Hrithik Gopinath
- Shrewsbury High School
  Student – Class of 2024

Preamble: Statement of Purpose

The consensus recommendation driven by expert physicians on the American Academy for Sleep Medicine, the National Sleep Foundation, and the American Academy for Pediatrics supports 8 to 10 hours of sleep each night for youth in the 13 to 18 year age range (Wise ML, et al. *J Clin Sleep Med* 2016). Yet data from multiple, large observational studies indicate that less than half of teeangers currently capture the requisite sleep time (Widome R, et al. *JAMA Pediatrics* 2020). Data from the peer-reviewed scientific literature yield a clear signal that this 'sleep debt' - coupled with the evening chronotype (preference for late bedtimes, and later wake times) associated with development through the teenage years - creates an increased risk to mental health and physical well-being (Swaab H, et al. *Eur Child Adolesc Psych* 2018). The authors of these studies posit that these risks are likely to lead to long-term health sequelae that negatively impact quality of life.

Further, the data suggest that concomitant sleep debt and emergence of the evening chronotype in the teen years contributes to (1) suboptimal academic performance, and (2) increased risk to the general safety of high school students in the United States (Keating XD, et al. *Qual Life Res* 2015).

Given the clear trends in the peer reviewed literature, the likely contributions of sleep debt to mental well being and academic performance, and the increased risk of behavioral disorders and to general safety of high school students, the members of the Research Task Group sought to review the extant data from relevant scientific journals along with consensus recommendations from noteworthy Academies of specialist clinicians. We therefore summarize herein several relevant data sets on the biology of sleep and recommended hours of sleep. In addition, we present position statements on start times by major professional organizations and our findings on how adjusted school start times have impacted students' sleep deficits. In addition, the report highlights school adjusted start time effects indicated on students' academics, health, and safety. Finally, we include data on sleep hygiene followed by conclusions and recommendations for other areas of research based on the Sleep Health Advisory Committee mission.

Section 1: the Biology of Sleep

Circadian Rhythm

Research on the circadian rhythm explains what the circadian rhythm is and how this rhythm changes as humans reach adolescence (Allada & Bass, 2021; Hagenaeur, 2009; Saxig, 2012). Circadian rhythm is derived from the Greek *circa diem*, meaning "about a day." It is defined as the intrinsic time-keeping system that helps regulate the sleep-wake cycle and a number of other physiologic mechanisms. This time-keeping system runs through the hypothalamus (SCN cells). During puberty, this system experiences anywhere from one to three-hour delays, and for many adolescents, this could result in a sleep-wake phase disorder, known as Delayed Sleep-Wake Phase Disorder (DSWPD). DSWPD is the most common circadian rhythm disturbance in adolescents and young adults. It is marked by a delay in the circadian phase that promotes wakefulness until later at night and drives sleep later into the morning. This disorder is associated with negative outcomes such as lower grades, alcohol and tobacco usage, and elevated anxiety and depression scores. To help reduce the incidence and negative outcomes of DSWPD, and for optimal health and functioning, the National Sleep Foundation and the American Academy of Sleep Medicine recommend 8 - 10 hours of sleep for teens.

Section 2. Association of School Start Time with Improved Outcomes

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Healthy school start times (no earlier than 8:30AM) have been identified by most major professional associations as follows:

- American Academy of Pediatrics
- American Academy of Sleep Medicine
- American Medical Association
- American Psychological Association
- National Association of School Nurses
- National Parent Teacher Association
- Massachusetts Interscholastic Athletic Association (MIAA)

Delayed Start Times Reduce the 'Sleep Deficit' and Better Align with the Typical Teenage Evening Chronotype

In August 2017, the Cherry Creek School District (CCSD), a diverse district of ~55,000 students in suburban Denver, Colorado, changed school start times, delaying high schools (HS grades 9–12, typical ages 14–18 years) by 70 min (to 8:20 am) and middle schools (MS, grades 6–8, typical ages 11–14 years) by 40–60 min (to 8:50 am), while moving elementary schools (ES, grades K-5, typical ages 5–11 years) 60 min earlier (to start at 8AM). Meltzer et al. (2021) examined the impact of changing school start times on student sleep, including bedtime, wake time, sleep duration, sleep quality, and daytime sleepiness on students K-12. Outcomes were evaluated before and 2 years after the change in start times. Anonymous student surveys were administered on laptops or tablets during designated class periods. Approximately 28,000 students annually completed surveys.

Results:

- Elementary school (ES)
    - Earlier bedtimes and wake times after changing to an earlier start time were observed. ES students experienced a decrease in average weekday sleep duration of 11 minutes, with no difference in weekend duration. This decrease in average duration of sleep of 11 minutes is cited as not clinically significant.
    - The percent of younger ES students obtaining sufficient sleep duration or having poor sleep quality did not differ at post-change or 2 year follow up.
- Middle school (MS)
    - MS students experienced longer sleep duration of 29 minutes per weekday
    - MS students got an extra 2.4 h of sleep per week. This resulted in a significant increase in the percent of students who obtained sufficient sleep after implementation of later start times (MS: pre 40.5%, post 61.0%). MS students reported a slightly later average weekday bedtime (9 minutes) but a much later average weekday wake time (37 minutes).
    - Weekend oversleep decreased post-change by an average of 32 minutes.
    - Key point: Consistent with previous studies, weekday bedtimes for MS and HS students were not significantly or proportionately delayed with later start times, yet weekday wake times were significantly later. **In other words, students don't stay up later as a result of later start times.**
- High school (HS)
    - HS students experience significantly longer sleep duration of 45 minutes per weekday.

- Sleep duration showed the greatest change for HS students, who obtained an extra 3.8 h per week. This resulted in a significant increase in the percent of students who obtained sufficient sleep after implementation of later start times (HS: pre 30.4%, post 62.7%).
- Weekend oversleep decreased post-change by an average of 77 minutes.
- HS students reported a slightly later average weekday bedtime (14 minutes) but a later average weekday wake time (60 min).
- Key point: Consistent with previous studies, weekday bedtimes for MS and HS students were not significantly or proportionately delayed with later start times, yet weekday wake times were significantly later. **In other words, students don't stay up later as a result of later start times.**

The University of MN published a report that analyzed data from 8 public high schools in 5 school districts in three states - Minnesota, Colorado, and Wyoming. The goal was to examine whether or not a delay in start time for high school students had an impact on their overall health and academic performance. Over 9,000 students were individually surveyed about their daily activities, substance use, and sleep habits.

In the table below, it is clear that as school starts later, an increasing number of high school students get 8 or more hours of sleep on school nights. Schools that started around 7:30AM saw roughly a third to less than half of the student population get 8 or more hours of sleep.

Table 4. Percent of High School Students Sleeping At Least 8 Hours Per School Night by School Start Time

School Start Time	**7:30 AM**	**7:35 AM**	**8:00 AM**	**8:00 AM**	**8:05 AM**	**8:20 AM**	**8:35 AM**	**8:35 AM**	**8:35 AM**	**8:55 AM**
School Year	2010-2011	2011-2012	2011-2012	2010-2011	2011-2012	2010-2011	2010-2011	2010-2011	2010-2011	2012-2013
District & State	Boulder Valley School District, CO	Teton County Schools, WY	Boulder Valley School District, CO	Mahtomedi School District, MN	Boulder Valley School District, CO	St. Louis Park High School, MN	South Washington Co., MN	South Washington Co., MN	South Washington Co., MN	Teton County Schools, WY
School	Fairview High School	Jackson Hole High School	Boulder High School	Mahtomedi High School	Fairview High School	St. Louis Park High School	Woodbury High School	East Ridge High School	Park High School	Jackson Hole High School
Sample Size	333	446	1379	884	1353	902	1249	960	1407	459
Sleep ≥ 8 hours/night	**33.6%**	**44.2%**	**44.5%**	**49.7%**	**42.5%**	**49.8%**	**57.0%**	**58.9%**	**60.0%**	**66.2%**

One study investigated the relationships between high school start times and sleep duration via actigraphy across 20 cities. Study participants were 15 years of age (n = 823) when the study was conducted. Study participants were asked to wear a

wrist-worn accelerometer for 1 week, and this was used to collect data on sleep onset and offset, 24-hour sleep duration, wake after sleep onset and sleep maintenance efficiency.

This was an ethnically diverse sample of adolescents. On average, adolescents were 15.5 years old (SD = 0.6, Range = 14.7–17.7 years), 47% male, ethnically diverse (e.g. 44% black, 26% Hispanic/Latino), and had varied family structures (32% lived with biological mother and biological father). The household incomes for 27% of the sample were below the poverty line, and 34% of primary caregivers completed high school or less education. Most of the adolescents attended public school (89%).

Adolescents with school start times at 8:30AM or later had an overall sleep duration that was 21 to 34 minutes longer than those with earlier start times (before 07:30, 07:30-07:59, and 08:00-08:29). When analyzed continuously, the study found that for every 1-hour delay in school start times, sleep duration was 21 minutes longer due to later wake times of 32 to 64 minutes. Even modest delays in high school start times (> 10 minutes) are associated with increased sleep duration. Sleep duration did not differ significantly by household income to poverty line ratio groups. Adolescents with the latest start time, 08:30 or later, achieved an estimated 7.6 hours of sleep duration, significantly longer than the adolescents in other start time categories; yet it does not meet the minimum hours of sleep per night recommended by the American Academy of Sleep Medicine, which is 8 to 10 hours per night for children aged 13-18.

Berry, K et al. (2021) followed a cohort (n= 2,414) of students from 5 Minnesota high schools to evaluate the impact of school start times. Participants were enrolled in ninth grade (Baseline) when all schools started early (7:30 or 7:45 A.M.). At Follow-Up 1 (10th grade) and Follow-Up 2 (11th grade), two schools had delayed their start times by 50 and 65 minutes while three comparison schools started at 7:30AM. After 2 years of delayed start times, students in the policy change schools relative to the comparison schools reported:

- 5% decrease in prevalence of oversleeping and being late to class
- 6% decrease in prevalence of feeling sleepy

Section 3. Safety

Motor Vehicle Crashes

Meltzer et al. (2021) investigated the impact of delayed school start times on high school students' self-reported daytime drowsiness and teenage motor vehicle crash (MVC) rates. In their longitudinal study, the authors administered an anonymous, online survey to 10th and 11th grade students in the Cherry Creek School District (CCSD), Colorado, where their school start time was delayed 70 minutes (7:10 am to 8:20 am). To gauge the association of delayed school start times on the variables of daytime drowsiness and MVC rates, the researchers administered the survey to regular drivers at three time points: pre-change (spring 2017), post-change (spring 2018), and follow-up (2019). Response rates were 1,642 students pre-change (51.9%), 2,029 students post-change (59.8%), and 2,452 students follow-up (60.4%). In addition, the researchers gathered Colorado Department of Transportation data (identifiers removed) on teen MVC rates from 2015-2019 for CCSD (Arapahoe County) and three neighboring counties where no school start time change had been made.

The data was examined for peak-hour traffic MVC rates on weekdays, as well as MVC rates on weekends and summers. Finally, the researchers considered the most frequently occurring types of MVCs in their analysis.

Results indicated that, compared to the baseline numbers, CCSD students reported:

1. **Less frequent drowsy driving post-change** (10.7% less than baseline) and again at follow-up (9.8% less than baseline).
2. **Significant decrease in weekday, teen MVC rates** (specifically afternoon, rear-end crashes – the kinds of crashes involving drowsy drivers) in Arapahoe County post-change and follow-up, with no significant changes in these rates for the surrounding counties, and no significant changes for weekend rates in all three counties.

Despite several limitations of their report (including the question of the reliability of self-reported daytime drowsiness and the need to take into account other factors that might contribute to MVC rates for this population), the authors still conclude their report noting the significance of their study in contributing to evidence-based reports supporting delayed school start times. Notably, the reduction in daytime drowsiness and MVC rates were maintained two years later, suggesting the staying power of implementing this policy change.

Vorona et al. (2014) used two-sample Z-tests to compare the number of teen crashes in two Virginia counties with similar demographics and geographically annexed (one with an earlier school start time, and one delayed by 85 minutes) as supplied by the Virginal Department of Motor Vehicles (identifiers removed). Results show that crash rates during the times that teens would typically travel to and from school were statistically significantly higher (48.8/1,000 versus 37.9/1,000; p=0.04) in the county with earlier school start times. This study was a follow-up to their previous study (2011) that investigated the impact of delayed school start times on the number of teen motor vehicle crashes in two other Virginia counties over two years. By replicating their previous study, the researchers contribute four years of evidence suggesting that delayed start times reveal a statistically significant reduction in motor vehicle accidents in teens.

Sports Injuries

In addition to safety concerns of teen drowsiness contributing to motor vehicle accidents, sports injuries related to sleep deprivation is another area of concern for teens' safety. As of this writing, very few studies have investigated this topic; however, a preliminary report by Consumer Health News (2012) warns that sleep deprivation yields an increased risk of sports injuries in teens. In a study of 112 California middle and high-school aged teenage athletes, the researchers found that student athletes who slept 8 or more hours were 68% less likely to experience a sports-related injury than their sleep-deprived, peer athletes. In addition, as students got older, they were also more likely than their younger peers to experience a sports injury (2.3 times more likely per year of advanced age).

Section 4. Mental Well-Being, Physical Health

Mental Well-Being

Not only do adolescents with insufficient sleep have an increased risk of suicidal ideation, but the risk may be similarly increased in adolescents whose parents also have insufficient sleep, raising some interesting questions about multigenerational environmental and/or genetic factors.

In sum, sleep has an important influence on mood and the development of depressive symptoms in adolescents. Although insufficient sleep and daytime sleepiness seem to have the most robust relationship with mood dysregulation, poor-quality sleep and irregular sleep patterns are also associated with depressed mood. Importantly, from a

clinical standpoint, improvements in sleep may lead to improvements in mental health functioning (and vice versa).

- Most American teenagers are sleep deprived: Fewer than one in four U.S. high school students gets the recommended eight hours of sleep per night.
- Researchers who study the relationship between sleep and depression are unanimous: Adequate sleep could greatly improve many U.S. teenagers' mental health.

"Perpetually fatigued adolescents look and feel depressed," says Rachel Widome of the University of Minnesota. Her research links adequate sleep to fewer symptoms of depression among teenagers. In a 2019 study, Widome and colleagues showed that about one in three students who slept less than six hours per night had a high number of depression symptoms; this suggests a significant deleterious effect when compared to the one in ten rate of depressive symptoms in students who slept in the range of 8-10 hours.

"Poor sleep and depression are reinforcing—depression interferes with sleep, and not enough sleep leaves someone feeling like they don't have energy to engage in life, which is a symptom of depression."

The notion that anyone "can push through on little sleep with little cost to mental health is a myth," says Andrew Fuligni of the University California, Los Angeles. His research demonstrates that despite some individual variation, most teenagers need about 8.5 hours of sleep to function at their best.

"Mental health is very sensitive to sleep," he explains. "To operate at peak levels—emotionally and intellectually—most teens should sleep between eight and 10 hours each night. Less than seven and more than 11 hours is unhealthy."

Addiction

Several papers indicate that the diagnosis and treatment of primary sleep disorders, particularly in adolescents, can prevent the development of addiction in susceptible individuals (Jacobs W, et al. *Adv Exp Med Biol* 2021).

Further, the authors argue that the relation is bi-directional, and a review of the evidence shows that sleep/alertness disturbance affects all phases of the addiction cycle, including the initiation, maintenance, and relapse of substance use disorders (Roehrs T, et al. *Pharmacol Biochem Behav* 2021).

Suicide

Importantly, from a clinical standpoint, improvements in sleep may lead to improvements in mental health functioning (and vice versa) - and in turn, mental well-being. Owens J, et al. (*Pediatrics*, 2014) reported:

- A troubling association between sleep loss and increased suicidality in adolescents is of paramount importance for pediatricians to recognize.
- A number of recent studies have focused on the possible relationship between sleep and suicidal ideation: sleeping less than 8 hours at night seems to be associated with an almost threefold increased risk of suicide attempts in the teen population.

Physical Health

Stanford Medicine

High Cost of Sleep Deprivation Among Teens

"Among Teens, Sleep Deprivation An Epidemic"

School districts around the country have been looking at one issue over which they have control concerning the health risks associated with sleep problems in teens: when school starts in the morning. A trend set by Edina, Minnesota, where they conducted a landmark experiment in student sleep in the late 1990s. They shifted start time 70 minutes from 7:20 am to 8:30 am, and University of Minnesota researchers looked at the impact of change. They found that students felt less depressed and less sleepy during the day and more empowered to succeed. It was found that no comparable improvement in student well-being in surrounding school districts where start times remained the same.

Based on these findings, the entire Minneapolis Public School District shifted start times for 57,000 students at all schools in 1997 found similarly posted results. They found attendance rates rose and students reported getting an hour's more sleep each school night which equated to 5 additional hours of sleep a week. This countered skeptics who argued that the students would respond by just going to bed later.

Other studies have reinforced the link between later start times and positive health benefits.

A 2010 study at an independent high school in Rhode Island found that after delaying the start time by just 30 minutes, students did sleep more and showed significant improvements in alertness and mood.

A 2014 study in 2 counties in Virginia found that teens were much less likely to be involved in car crashes.

In 2014 – the American Academy of Pediatrics issued a strong policy statement encouraging middle and high school districts across the country to start school no earlier than 8:30 am to help preserve the health of the nation's youth.

Lack of sleep is a contributor to obesity in adolescents: impacts on eating and activity behaviors (Jean-Philippe Chaput* and Caroline Dutil).

Longer sleep duration was associated with lower adiposity indicators, better emotional regulation, better academic achievement, and better quality of life/well-being in that review.

Evidence strongly implicates early school start times as a key modifiable contributor to insufficient sleep in adolescence. A growing body of evidence has shown that delaying school start times is an effective countermeasure to chronic sleep deprivation and has a wide range of potential benefits to students with regard to physical and mental health, safety, and academic achievement.

Section 5. Academics

The following data was collected in a study that compared Minnesota, Colorado, and Wyoming school districts. The school start and end times before and after the changes are:

- South Washington County (SWC)-(MN)— Park High School
  - Before: 2008 – 2009: 7:35 AM – 2:05 PM (4 periods) After: 2009 – 2010: 8:35 AM – 3:05 PM (6 periods + zero hour 7:15 AM- 8:15 AM Mon- Thurs) **60 minute change**
- South Washington County (SWC)-(MN)—East Ridge High School (a new school in 2009 -2010)
  - 8:35 AM – 3:05 PM (6 periods + zero hour 7:30 AM- 8:20 AM)
- Boulder (CO) High School – Start and End Times
  - 2010-2011: 7:30 a.m. to 4:00 p.m. 8-period day 2011-2012: M 8-4:30; T 8-3:30; W 9-3:30; Th 8-:3:30; F 8-4:30 p.m. Modified block schedule **30 minute change every day**, except **Wednesday**, which is a **1.5 hour change**
- Fairview (CO) High School – Start and End Times
  - 2010-2011: 7:35 a.m. to 3:00 p.m. Modified block schedule 2011-2012: 8:05 a.m. to 3:20 p.m. Modified block schedule **30 minute change**
- Jackson Hole (WY) High School

- 2011-2012: 7:35 a.m. to 2:45. Modified block schedule 2012-2013: 8:55 a.m. to 3:50 p.m. Modified block schedule (+ some zero hour courses) **80 minute change**

Grade Level	District/School					
	Fairview	**Boulder**	**Mahtomedi**	**Saint Louis Park**	**South Washington County**	**Jackson Hole High School**
All Grades	**Increase**	**Increase**	**Increase, Decrease**	*ns*	**Increase, Decrease**	**Increase**
9th Grade	**Increase**	N/A	**Increase, Decrease**	N/A	N/A	**Increase**
10th Grade	*ns*	N/A	**Increase, Decrease**	N/A	**Increase**	**Increase**
11th Grade	**Increase**	N/A	**Increase**	N/A	**Increase**	**Increase**
12th Grade	**Increase**	N/A	**Increase, Decrease**	N/A	**Increase**	**Increase**

- The data from the table above was collected in an experiment which compared 6 different high schools. The 6 high schools all pushed their school start times to later in the morning. The schools measured the change in average GPA before and after the school start time changed (Wahlstorm et al., 2014, p. [Page 40]).
- Overall there was an increase in GPA across the board; although, in some scenarios, there was no significant change (Wahlstorm et al., 2014, p. [Page 40]).

Table 38. Independent group comparisons of standardized test scores. Subject areas with observed changes are reported. Significant findings are in **Bold**. More details are available in Appendices C-H.

Test/Tested Subject	District/School					
	Fairview	**Boulder**	**Mahtomedi**	**Saint Louis Park**	**South Washington County**	**Jackson Hole High School**
Math	*ns*	*ns*	N/A	*ns*	**Increase**	**Decrease**
Reading	*ns*	*ns*	N/A	*ns*	*ns*	*ns*
Writing	**Decrease**	*ns*	N/A	*ns*	*ns*	*ns*
Science	*ns*	*ns*	N/A	Not Tested	*ns*	*ns*
Composite (ACT or PLAN)	*ns*	**Increase**	**Increase**	*ns*	*ns*	*ns*

*Note: ns = Not significant; N/A = Change in scoring scales; Not Tested = No test administered in that area

- The data from the table above compared the standardized test score before and after the timings of school changed and, overall, it had an increase, although it was very minor. For the most part, the change in scores was not significant (Wahlstorm et al., 2014, p. [Page 41]).

Grade Level	District/School					
	Fairview	Boulder	Mahtomedi	Saint Louis Park	South Washington County	Jackson Hole High School
All Grades	*ns*	*ns*	Increase (95.0% to 95.8%)	*ns*	Increase (94.5% to 94.7%)	*ns*
9th Grade	*ns*	N/A	*ns*	*ns*	*ns*	Increase (93.7% to 95.0%)
10th Grade	*ns*	N/A	Increase (95.9% to 96.6%	*ns*	*ns*	*ns*
11th Grade	*ns*	N/A	*ns*	*ns*	Increase (94.2% to 94.7%)	*ns*
12th Grade	*ns*	N/A	Increase (92.2% to 94.0%)	*ns*	*ns*	*ns*

- Attendance had also increased across the board by an average of 1%; this includes the decrease of tardies, absences, etc. (Wahlstorm et al., 2014, p. [Page 37])
- After the experiment, some key findings include “positive findings include a significant reduction in local car crashes, less absenteeism, less tardiness, as well as higher test scores on national achievement tests” (Wahlstorm et al., 2014, p. [Page 52]). When delaying the start time of high school, you can have an increase in academic quality which will result in prosperity and a bright future.

Section 6. Sleep Hygiene

Sleep Hygiene is defined as healthy sleep habits. “Children who get enough sleep have a healthier immune system, and better school performance, behavior, memory, and mental health,” (American Academy of Pediatrics, 2020). Based on a National Sleep Survey in 2014, 90% of parents reported that sleep health for their children is important. Good sleep habits start prior to going to bed. Both the American Pediatric Association and Perfect and Frye reviewed several behavioral strategies to increase healthy sleep habits.

The first strategy is to have open communication with your children to make changes to promote sleep, such as changing the routine (e.g., homework after school). This dialogue can help to identify problems and develop potential solutions. The second strategy is to stay involved in your child’s sleep routine. Parents that are more involved will lead to healthier sleep habits. Those that are not involved may not be aware that their child is not getting enough sleep. Caregivers also need to make sure there is enough time for sleep and should account for the time it takes their child to fall asleep.

Sleep and wake times should align with the recommended amount of sleep. It is also recommended to establish and keep consistent bedtime routines. Parents should try to pair enjoyable activities with the bedtime routine. They also want to avoid reinforcing problematic behaviors that may delay bedtime. Routines should ensure a positive environment and have the child fall asleep independently. Lastly, technology should be limited prior to bedtime. The blue light can cause a decrease in melatonin and be distracting (Allen et al., 2016).

Other strategies with less research include waking up at the same time each day, changing the bedroom environment as needed, and paying attention to eating and sleeping habits. Children may vary on the amount of light and noise needed to fall and stay asleep. Caffeine and large meals before bed can impact sleep quality. Owens (2014) found children who had larger intake of caffeine reported more sleep difficulties. Lastly, the American Pediatric Association recommends that children engage in some physical activity throughout the day. Those that engage in some physical activity have an easier time falling asleep. Overall, there are many factors that can impact healthy sleep habits including communication between children and caregivers, consistent routines, bedroom environments, technology use, and caffeine intake.

Section 7. Behavioral Conditions: ADHD and Autism Spectrum Disorder

Summary comments:

1. Wise MS et al. JCSM 2016
    a. AASM consensus recommendations
    b. Physical domains: N = 25 - 75,000
    c. Mental health: N = 100 - 30,000
    d. Limited analysis of ADHD, ASD: these disorders are typically diagnosed between 4 - 10y, with initial emergence >12y unusual
    e. Highlights dearth of data on impact of chronotype on ADHD, ASD - but later bedtimes, longer sleep latency suggest later school start times would ameliorate rather than exacerbate existing conditions
    f. Focused on duration, not chronotype
    g. Meta-analysis finds poor outcomes: immune, metabolic, cardiovascular, mental health
    h. Calls out school start times as an important downstream effector of sleep habits, recommends further studies (including interventional) for policy making

2. Swaab H et al. ECAP 2018 (AASM
    a. ADHD N = 44, ASD N = 68, Control N = 243
    b. Strong association of evening chronotype with behavioral problems, severity of ASD, ADHD symptoms
    c. Found stat sig (p<.05 to p<.001) association with multiple sleep disorders; co-morbid anxiety, depression, etc. (sample table below)
    d. Age ~10y, so cannot draw absolute conclusions to HS age group - but shift toward evening chronotype would likely strengthen associations

Table 2 Differences in sleep problems between ADHD, ASD, and controls

	ADHD ($N = 44$)	ASD ($N = 67$)	Control ($N = 243$)	p
DIMS	11.05 (4.13)	12.06 (3.69)	8.74 (2.78)	ADHD and ASD > Control***
SBD	4.20 (1.46)	4.25 (1.69)	3.98 (1.17)	NS
DA	4.02 (1.49)	4.25 (1.52)	3.70 (1.12)	ASD > Control**
SWTD	10.91 (4.01)	10.62 (3.79)	9.00 (2.59)	ADHD and ASD > Control***
DES	9.00 (3.20)	8.91 (2.73)	7.44 (2.06)	ADHD and ASD > Control***
SHY	3.75 (2.16)	3.71 (1.94)	2.97 (1.43)	ADHD > Control* and ASS > Control**
TSP	42.93 (10.99)	43.74 (9.79)	35.83 (7.22)	ADHD and ASD > Control***
Prevalence[a]	28 (63.6%)	44 (64.7%)	61 (25.1%)	ADHD and ASD > Control***

Values are means and standard deviations

DIMS Disorders of initiating and maintaining sleep, *SBD* sleep breathing disorders, *DA* disorders of arousal, *SWTD* sleep-wake transition disorders, *DES* disorders of excessive somnolence, *SHY* sleep hyperhidrosis, *TSP* total sleep problem score

NS not significant ($p > 0.05$)

* Significant at the 0.05 level

** Significant at the 0.01 level

*** Significant at the 0.001 level

[a] Prevalence: total score >39

Conclusions and Recommendations for Further Study

Conclusions

1. Extant data from the peer reviewed literature show clear signals that sleep debt coupled with the shift to evening chronotype adversely impact high school students'
    a. Mental well being (higher incidence of depression, anxiety, suicidal ideation)
    b. Physical disease (e.g. risk of obesity, diabetes)
    c. Behavioral disorders (exacerbates existing conditions including ADHD, ASD)

2. Trends in the data also suggest negative impact / increased risk in other areas
    a. Academic performance
    b. General safety (e.g. automotive accidents)

    c. Long-term health sequelae that negatively impact QOL over time

3. Study limitations
    a. While the data yield clear signals, not all outcomes show statistically significant differences (often the result of subjective, survey-based measures)
    b. Much of the data is derived from meta-analyses of multiple studies, which means data sets may not be directly comparable due to different study designs, statistical analyses, student demographics, etc.

Recommendations

Based on the conclusions derived from the Research Task Group's review of the literature and guidance from medical experts that populate the AASM, NSF, and AAP, we suggest the following next steps:

1. Present key findings, rationale, and recommendations at an upcoming Shrewsbury School Committee meeting; include public Q&A session for interested parties

2. Continue analyses of other factors and dynamics that would be affected by shifting school start times
    a. Logistics
    b. Budget
    c. Child Care

3. Engage with stakeholders outside of the Shrewsbury school district to capture additional inputs to better inform a future decision on shifting school start times
    a. Neighboring districts / districts with comparable demographics
    b. Subject matter experts / KOLs in the field of sleep requirements for youth across various developmental stages

4. Consider any future shift in school start times for potential interventional 'pre-post' studies
    a. Measure mental well being, physical health, etc. for some period of time prior to the delayed start time; take same measurements during and post delayed start time to quantify differences
    b. Track quantitative metrics on safety, hours of sleep prior to, during, and post-delayed start to obtain longitudinal readouts spanning multiple time points

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