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Adolescent sleep health and school start times: Setting the research agenda for California and beyond: A research summit summary

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ABSTRACT

In fall 2019, California passed and signed into law SB328, the first US statewide legislation explicitly designed to protect adolescent sleep health by requiring most California public school districts to start no earlier than 8:00 AM for middle schools and 8:30 AM for high schools. Recognizing the unique opportunity presented by the bill's 3-year implementation period, a group of experts in adolescent sleep and school start times held a virtual summit on January 22-23, 2021 to (1) summarize the research on adolescent sleep and school start time change; (2) develop recommendations for relevant, refined, and innovative research areas and research questions; (3) provide input regarding research design, methodology, and implementation; and (4) offer a forum for networking, exchanging ideas, and establishing interdisciplinary research collaborations. Participants represented a multidisciplinary range of academic backgrounds including sleep and circadian biology, neuroscience, education, medicine, public health, mental health, safety, public policy, economics, implementation science, criminology, diversity studies, and science communication. This paper summarizes summit presentations regarding current knowledge on adolescent sleep health and school start times and key research recommendations from small group workshops on topics including research design and tools, methodological issues, sleep health disparities, logistical challenges in conducting school-based research, public-health impact, and novel and expanded approaches to research.

In fall 2019, California passed and signed into law SB328, the first US statewide legislation explicitly designed to protect adolescent sleep health by aligning secondary school hours with the substantial body of scientific evidence regarding adolescent sleep needs and timing. This landmark legislation, enacted in the state with the nation's greatest number of public-school students, requires most California public school districts to start no earlier than 8:00 AM for middle schools and 8:30 AM for high schools. The bill received international attention and is considered a benchmark for similar legislation across the US and around the globe. Moreover, the law's 3-year implementation period provides an unprecedented and timely opportunity for researchers interested in translating adolescent sleep research into policy.

Recognizing this unique opportunity, a group of experts in adolescent sleep and school start times, spearheaded by the national nonprofit Start School Later/Healthy Hours, met to discuss ways to develop thoughtful, timely, innovative, and translational research

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recommendations. The result was a virtual *Summit on Adolescent Sleep and School Start Times: Setting the Research Agenda for California and Beyond*,[1] hosted on January 22-23, 2021 by the Department of Psychiatry and Behavioral Medicine at the Stanford University School of Medicine, a historic home for adolescent sleep research.[2]

The summit offered the opportunity to learn, discuss, and make recommendations regarding future research on adolescent sleep and school start times, as well as to explore collaborations among a multidisciplinary roster of speakers, workshop leaders, and participants. Participants represented a wide range of academic backgrounds including sleep and circadian biology, neuroscience, education, medicine, public health, mental health, safety, public policy, economics, implementation science, criminology, diversity studies, and science communication. (See Appendix for a list of co-chairs, speakers, and workshop leaders). The summit's objectives were to: (1) summarize the research on adolescent sleep and school start time change; (2) develop recommendations for relevant, refined, and innovative research areas and research questions; (3) provide expert input regarding research design, methodology, and implementation; and (4) offer a forum for networking, exchanging ideas, and establishing interdisciplinary research collaborations.

This paper summarizes key summit proceedings, including but not limited to opportunities related to the California statewide mandate. It provides (1) a synopsis of a series of presentations by experts in their respective fields summarizing the state of current knowledge on adolescent sleep health and school start times, and (2) key messages from the small group breakout discussion sessions on topics including research design and tools, methodological issues, logistical challenges in conducting school-based research, public-health impact, and novel and expanded approaches to research.

Context

The 3 decades since groundbreaking studies by Mary A. Carskadon and colleagues[3-9] have seen tremendous growth in the understanding of adolescent sleep-wake patterns, circadian timing, underlying bioregulatory processes, and environmental constraints, along with the negative consequences of deficient (ie, insufficient, poorly timed, irregular, and/or poor quality) sleep on physical, psychological, behavioral, and cognitive wellbeing. As this research emerged, convergent social and economic forces were concurrently leading many school systems to stagger starting times with tiered busing, which often resulted in older adolescents starting classes considerably earlier than the 8:30 or 9 AM bell times typical prior to the late 20th century.[10-13] These changes often required adolescents to wake before sunrise to attend classes in the 7 AM hour, with bus pick-up and commute times considerably earlier. Today over 80% of US secondary schools require students to attend classes prior to 8:30 AM, with the average public high school starting at 8 AM and 10% starting before 7:30 AM.[14,15]

Inspired by the early research on adolescent sleep needs and patterns, the late Mark Mahowald and colleagues at the Minnesota Medical Association urged Minnesota's school districts to start classes later, eventually prompting 2 districts (Edina in 1996 and Minneapolis in 1997) to delay starting times. These changes allowed Kyla Wahlstrom, Director of the University of Minnesota's Center for Applied Research and Educational Improvement (CAREI), to conduct the first large-scale school start time outcome studies, documenting that delaying high school classes leads to increased sleep associated with later wake times, not later bedtimes, and numerous health and academic benefits.[16] These findings have subsequently been replicated and expanded for middle and high school students in hundreds of US districts. Subsequent studies have also delineated feasible and affordable ways to delay bell times, involving large and diverse districts, such as Seattle (WA) Public Schools and Fairfax (VA) County Public Schools, as well as smaller suburban and rural districts throughout the country ranging from Saco, ME to Palo Alto, CA.[17]

These efforts and the significant evidence base behind them established early school start times as the leading factor, among the many psychosocial, cultural, and biologic factors influencing adolescent sleep, currently known to be both modifiable and to have a measurable impact at the population level.[2,18,19] Based on these studies, the American Academy of Pediatrics in 2014 issued a policy statement—subsequently supported by the American Medical Association, American Academy of Sleep Medicine, and other major healthcare, education, and civic organizations—recommending that middle and high schools start classes no earlier than 8:30 AM.[20] A 2019 consensus letter signed by over 120 experts in medical research, public health, medicine, sleep medicine, pediatrics, psychiatry, adolescent psychiatry, and preventive medicines similarly stated that "the volume, breadth, consistency, and strength of the peer-reviewed scientific research" supporting later school start times are "unequivocal, exceeding the high standards for public health and education policy."[21] Reaffirming this consensus, an October 2019 report by a Pennsylvania Joint State Government Commission concluded that the benefits of starting secondary schools no earlier than 8:30 AM are supported by "robust research," obviating the need for a proof-of-concept program.[22]

Research on adolescent sleep and school start times

Sleep and circadian biology in adolescents

Many factors, both biologic and behavioral, influence human sleep behavior, often with interactions among them. Genetic factors have been shown to influence sleep duration and circadian timing, sleep homeostatic control, and the sleeping EEG (electroencephalogram), though much remains to be learned about these mechanisms. Bioregulatory processes also help determine sleep length, circadian timing, and resulting waking alertness, and are thought to involve 2 factors: sleep homeostasis or sleep pressure ("Process S") and circadian timing ("Process C").[23]

Both bioregulatory factors—the circadian and sleep pressure systems—favor a delay in the timing of sleep during adolescence. The most prominent change in the circadian process is a delay in the timing of rhythms, including delays in both falling asleep and waking up. Such a pattern of delayed sleep has also been found in nonhuman juvenile mammals of at least 6 species, indicating a strong biologic component.[24,25] In humans, this pattern manifests itself by both a later "chronotype," a behavioral marker, as well as the secretion of melatonin later in the evening, a biologic marker. Melatonin is a marker for biologic night, "opening the window for sleep." The resulting delay in sleepiness, which happens naturally and reverts to earlier timing after young adulthood, is also affected by late evening light exposure and absence of morning light, both commonly experienced by modern adolescents.[26]

Sleep pressure has been measured by assessing EEG slow wave activity, a biomarker measurable in the sleeping brain. EEG slow wave activity marks a response to wakefulness, and adolescents build up EEG slow wave activity (sleep pressure) across the day more slowly than preadolescents, thus delaying the pressure to fall asleep and making it easier to stay awake longer.[27] On the other hand, the reduction in EEG slow wave activity (ie, sleep pressure) during sleep occurs at the same rate in adolescents and preadolescents, indicating similar sleep needs.[28] This means that adolescents who stay awake late, but need to wake up early, do not get sufficient sleep, estimated to be about 9-9.5 hours per night, with individual variation ranging between 8 and 10 hours.[29,30]

Given contemporary lifestyles, including late-evening light exposure and requirements to rise extremely early for school, plus teens'

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biologic changes, it is no surprise that many adolescents are getting too little sleep and waking at the wrong biologic time. This "deficient sleep" frequently culminates in poor alertness and attention in school and on the road, as well as compromised school performance and the plethora of mental, behavioral, and physical health issues described in subsequent sections. In addition, while sleep deficiency is widespread across the adolescent population, increasing evidence shows significant sleep health disparities by ethnicity, race, gender, and socioeconomic status.[12,31-35] Children and adolescents from families with lower socioeconomic status (SES) obtain less sleep and have more erratic sleep-wake schedules than peers from higher SES families.[36] Furthermore, racial and ethnic minority adolescents are at an increased risk of having shorter sleep duration and poorer sleep quality than their white peers.[33] In one study, for example, black adolescents slept between 20-30 minutes less per night than their white peers (as measured by actigraphy), with more frequent naps and greater social jetlag.[37] Broadly speaking, these differences in sleep patterns appear to be due to a range of factors, including socioeconomic, cultural, sleep environment characteristics (eg, light and noise), and the role of historic and pervasive discrimination.

Several research teams are now specifically examining the implications of racial and ethnic discrimination on adolescents' sleep. One study, for example, found that ethnic discrimination was associated with actigraphically estimated shorter sleep duration and sleep quality among a sample of ethnically diverse adolescents.[38] Another study, focused on coping strategies in racial and ethnic minority students attending US public schools, found that on days when adolescents reported greater discrimination, higher quality and more sleep (actigraphically measured) predicted more problem solving and seeking peer support ("coping"), less ruminating, and better well-being.[39] Undoubtedly, a greater understanding of adolescent sleep disparities will help to inform interventions, policies, and educational programs to minimize these disparities and their impact on health, behavioral, and educational outcomes.

Adolescent sleep and emotional and behavioral health problems

Despite reaching a peak stage of health in terms of their physical and cognitive functions, adolescents simultaneously experience sharp increases in morbidity and mortality.[40,41] This conundrum has been termed the "adolescent health paradox."[42] The paradox may in part be associated with the dramatic increases in psychological and behavioral health problems during adolescence. For example, not only do 50% of all lifetime cases of depression begin by age 14,[43] but adolescence is a peak period for such risky behaviors as initiating substance use and developing substance use disorders.[44,45] Furthermore, clear associations among many health risk behaviors, mental health disorders, and problems regulating both emotions and behavior are apparent in adolescence.[40,42] In adolescents, these associations are primarily focused on executive function deficits, including impaired decision making, reduced motivation, poor judgment and impulse control, and inattention. All of these capacities, in turn, are negatively impacted by poor sleep, which also affects emotional regulation and impairs reward-related decision making (ie, the perception of negative consequences for risk-taking behavior).[46-48] Adolescents are particularly vulnerable to these sleep-related impacts due to critical developmental changes in those brain centers such as the pre-frontal cortex controlling executive functioning.[49]

Importantly, even if a sleep problem does not meet criteria for a sleep disorder such as insomnia or a circadian rhythm disorder, the core components of deficient sleep—ie, insufficient sleep, circadian misalignment, and/or poor quality sleep—have been prospectively linked with mental and behavioral health problems in adolescents, including depression, anxiety disorders, substance abuse, risky behaviors, and suicide.[50-56] For example, adolescents who get insufficient or poor quality sleep are more likely to report symptoms of depression,[57] hopelessness, suicidal thoughts and attempts,[46,47] irritability, and impaired emotional regulation.[48] Furthermore, insufficient or otherwise disturbed sleep is associated cross-sectionally and longitudinally with risk-taking behaviors, including risky sexual activity, and use of alcohol, marijuana, and other drugs.[56,58-62]

Experimental evidence suggests a causal process through which sleep problems may dysregulate emotions and behavior, which in turn, can heighten risk for mental and behavioral health disorders.[62-65] Sleep restriction studies, for example, have shown that sleep-restricted adolescents have higher levels of anxiety, anger, fatigue, and confusion than adolescents who get sufficient sleep.[66] Sleep restriction is also associated with reduced positive, and increased negative, affect,[66,67] which may increase vulnerability to depression. Such changes in affective regulation may be linked to the role played by REM sleep in emotional processing and memory consolidation.[62,68] Because REM sleep disproportionately occurs in the early morning hours, moreover, curtailing adolescent sleep for early school start times may result in selective REM deficits, as well as longer-term consequences for emotional processing and regulation.[69]

Health and safety consequences of deficient sleep in adolescents

In adolescents, deficient sleep has both acute and downstream effects on physiology and physical health, affecting virtually every system of the body, and described in several review articles.[70-72] For example, the well-established association between sleep deficiency and obesity risk[73-75] is based on studies examining the impact of sleep restriction on neurohormones regulating hunger and satiety and on metabolic functions such as insulin resistance, as well as contributory behavioral factors such as reduced physical activity and altered eating patterns. Furthermore, both deficient sleep and obesity have a direct detrimental impact on cardiovascular health (eg, hypertension), metabolic disease (eg, type 2 diabetes) metabolic function, and systemic inflammation.[76-78]

Deficient sleep may contribute to both the development and exacerbation of underlying medical conditions through several basic mechanisms. These include the complex bi-directional relationship between sleep and immune response mediators (inflammatory markers).[79,80] For example, short sleep is associated with susceptibility to and slowed recovery from infection, including increased frequency of common infectious diseases,[71,81] and may also result in an attenuated antibody response to vaccines such as influenza and hepatitis B.[82] Furthermore, because there is also a bi-directional association between deficient sleep and pain in terms of increased pain perception and intensity and decreased threshold for and tolerance to pain, adolescents with chronic pain conditions may be particularly vulnerable to the effects of poor sleep with resulting functional disability.[83]

Finally, due in large part to some of the aforementioned deficits in executive functioning associated with deficient sleep (eg, poor impulse control, impaired decision making, and emotional dysregulation), sleep-deficient adolescents are at increased risk for a variety of injuries. This is a critical link, as accidental injuries, including motor vehicle crashes, are the number one cause of death in the adolescent population,[84] with over 60% of adolescent deaths due to injury-related causes associated with risk-taking behaviors.[50] Sleep-impaired driving resulting from deficient sleep is especially prevalent in adolescents.[85] Numerous studies have linked these sleepiness-related impairments to motor-vehicle crash risk, including several studies demonstrating that adolescent crash rates not only increase significantly in earlier starting high schools,[86-88] but also decline significantly after delays in school start times.[89-91] Although less well-studied, sleep loss may also be associated with pedestrian,[92] workplace,[93] and sports-related injuries,[94,95] as well as repeated injuries.[96]

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In addition, insufficient sleep is associated with health-risk behaviors that themselves may substantially increase the likelihood and severity of accidental injuries, including infrequent bicycle helmet and seat best use, and texting and drinking while driving.[97] Finally, recovery from injuries may be impaired; for example, sleep disruption may exacerbate or perpetuate many of the common sequelae of mild traumatic brain injury including depression, post-traumatic stress disorder (PTSD), and chronic pain, thus impairing rehabilitation.[98]

Deficient sleep, learning, and academic performance

Sufficient and high-quality sleep is required for acquiring, consolidating, and retrieving information across the lifespan. Extensive research in adolescents, including both naturalistic surveys and experimental, laboratory-based studies, have linked deficient sleep, including evening circadian preference, to impaired cognitive and behavioral performance, manifested by daytime sleepiness, irritability, impulsivity, distractibility, inattention, slower psychomotor response, and lack of motivation.[99-104] Even a single night of sleep deprivation markedly impairs brain function, restricting the ability to commit new experiences to memory.[105,106]

For these reasons adolescent students who sleep under 8 hours per night, are more likely to lose memory consolidation during sleep or learning opportunity the following day when their brains cannot function at full capacity. The combination of later bedtimes (whether due to circadian changes, homework, extracurriculars, socializing, and/or blue-light exposure) and forced early wake times often leaves adolescents in this sleep-deficient state, raising the possibility that relatively early school start times impair academic performance. Indeed, several studies suggest that students who align course schedules with their circadian schedule are more likely to perform better academically.[17,107] In addition, many studies have specifically associated earlier school start times with poorer academic achievement and school performance,[108-112] including reduced sustained attention[113] and higher rates of absenteeism, tardiness, and dropping out of high school.[114,115] Accumulating evidence also suggests that the chronotype of individual students, such as morning or evening preferences, can differentially affect academic and test performance.[116,117] One study, for example, systemically assessed the performance of young adolescents on intelligence tests as a function of individual chronotype, confirming a marked "synchrony effect" in which a match between a student's chronotype and time of day the test is taken yielded a 6-point difference in IQ score.[118]

School start times and overall outcomes

Accumulating cross-sectional evidence shows a linear association between school start time and sleep duration, whether sleep is estimated by daily diary or actigraphy.[119,120] Data from a wide variety of schools delaying start times also shows that when schools move bell times later, a greater proportion of students get more sleep and have more regular sleep-wake schedules.[16,90,121-125] Other studies show a dose-response relationship between sleep and school start time, with 8:30 AM class times the watershed mark at which half to two-thirds of all students get at least 8 hours of sleep.[90,119,126,127]

In addition to more and better-timed sleep, both cross-sectional and outcome studies have consistently associated later school start times with fewer signs of depression,[16,122,125,128] less stimulant and illegal substance use,[16,90,125,129] and lower car crash rates,[86-91,129,130] as well as with significant improvements in attendance, truancy, tardiness, suspensions, and graduation rates.[108,110,124,125,131,132] Conservatively considering only the impact on motor-vehicle crashes and graduation rates, the RAND Corporation projected that starting middle and high school classes no earlier than 8:30 AM would boost the US economy by $8.6 billion after 2 years, contributing $83 billion to the US economy within a decade, with an average annual benefit of $9.3 billion over 15 years. Remarkably, the report projects that within just 2 years these benefits would outweigh any costs districts might incur in changing bell times.[133]

While studies have not shown that delaying start times has a statistical effect on ACT scores,[16,114] some show a statistically positive effect on state-level achievement tests[110] and grades,[90,124] making later start times equivalent to being in a class with a third fewer students[108] and to having a teacher with instructional performance rated one standard deviation higher than peers.[134,135] Other studies show that academic benefits, including improved graduation rates and better grades and test scores, are disproportionately greater for students of lower socioeconomic status and for disadvantaged minorities.[110,130,136] Homeless and students who frequently change districts ("highly mobile" students) in later-starting schools also appear to have a statistically greater likelihood of remaining in school and graduating.[16] These disparities suggest that later start times may ultimately be a mechanism for reducing the opportunity gap.[131]

Academic improvements in already high-performing students are more difficult to measure, especially when a "ceiling effect" leaves little or no room for improvement. Some of these students may deceptively appear to "do just fine" on less than 8 hours of sleep per night, as evidenced in high achievement and participation in sports and other extra-curricular activities. For that reason, decreased social, emotional, and physical health due to deficient sleep may be the more pertinent indicators when measuring the impact of both sleep deficiency and delaying bell times in this cohort.

Research priorities and recommendations

As noted above, the depth, breadth, and consistency of the research base on adolescent sleep and school start times has already led to scientific consensus regarding the benefits of later school start times to adolescent sleep, health, safety, and overall wellbeing, as well as the feasibility of delaying start times in a wide variety of school settings. Nonetheless, the summit revealed several specific areas that would benefit from additional consideration and exploration.

Measures and data collection

Summit participants identified numerous ways to refine methods of collecting and analyzing data on adolescent sleep and school start times, as described below. Table 1 provides their specific suggestions, along with examples of how they might be applied.

Define optimal research designs

There remains a continuing need to clearly define and defend appropriate methodologies and standards of evidence for studying the impact of school start time change. Calls for additional studies, including randomized controlled trials, to confirm outcome measures are perhaps the inevitable consequence of mixing disciplines with different databases, methodologies, and standards of evidence. However, in defining optimal research designs going forward, researchers should consider that randomized controlled trials may not be appropriate, feasible, and/or ethical in assessing outcomes of multifactorial systemic changes like delaying school start times. For example, it is unlikely that any school district would volunteer to be randomized to have its schedule changed—a reluctance that in fact derailed a proposed trial of later start times in the United Kingdom.[137] Establishing study designs and standards of evidence appropriate to research with education and public policy implications is critical, as is disseminating these standards to researchers in diverse fields, as well as to the lawmakers, educators, and other stakeholders using this research to influence policy.

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Table 1
Methodology recommendations

Needs	Examples and commentary
Determine optimal research designs to test intervention effects, including rigorous naturalistic designs.	Randomized controlled trials may not be appropriate, feasible, and/or ethical in assessing outcomes of multifactorial systemic changes like delaying school start times. Determine how evolving standards regarding P values and the use of Bayesian models might affect study design.[1]
Consider whether a control group is necessary and, if so, determine the best strategies for establishing one.	In the case of California, how should "control" groups be established if schools exempted from the law (eg, rural schools) have different demographic characteristics?
Determine when and how to gather more objective data on large populations other than just using actigraphy.	Can we utilize ecological momentary assessment (eg, a "ping" on a smartphone or smartwatch) to capture real-time data, which could lead to longitudinal data to track causal effects?
Establish standards for studying long-term outcomes (eg, on health and sleep behavior) that control for developmental changes in students.	How can we collect longitudinal data of up to 10 years to examine outcomes for the same child over time, examining developmental factors potentially related to the starting time of the child's school?
Use a socio-ecological framework to measure outcomes when possible.	Ideal approaches consider that all outcomes affected by start time change are nested in a variety of systems— eg, individuals in households and households in communities. Reconsider common educational outcomes with a bidirectional dialogue between educators and basic researchers to ensure that controlled scientific methods are employed to inform real-world settings and vice versa.
Include more qualitative methods and data with objective measures.	Consider including open-ended response options to key questions in objective surveys. Surveys provide the "bones" for objective data, and open-ended responses provide the explanatory "meat" for those bones, potentially yielding more accurate or complete responses. Individual or focus-group interviews can also provide otherwise unknowable insights. Clusters of similarly themed responses, for example, can provide quasi-objective data to elucidate viewpoints and indicate relative strength of outcomes.
Move beyond small, controlled studies to remedy the discrepancy between model classrooms and real-world schools.	Re-examine large datasets (eg, from government or local agencies) to study academic outcomes relevant to sleep-dependent cognition.
Find ways to conduct research with minimal funding and that reduce financial and other burdens on participating schools.	Use pre-existing sources of data to reduce research funding needs.
Use unique data sources.	Consider using social media, low-cost wearables, and online data collection (eg, ecological momentary assessment of cognitive tasks, sleep diaries, attention, or mood ratings).
Identify ways to measure and report sleep that is most useful to colleagues in other fields, and ultimately to policymakers and other stakeholders outside the sleep research community.	To understand how to make sleep studies understandable and relevant to the lay population, have persons who are not professional researchers suggest novel ways to collect data and/or to read study reports.
Create more cross-disciplinary and community-engaged research opportunities.	Brainstorm the range of researchers and community stakeholders who have related interests in the effects of greater sleep duration and the later start time of schools.

[1] Harrington D, D'Agostino RB, Sr., Gatsonis C, et al. New Guidelines for Statistical Reporting in the Journal. *The New England Journal of Medicine.* 2019;381(3):285-286.

Increase sleep data granularity

Most studies of adolescent sleep and school start times have involved largely quantitative data, with a mix of both objective and subjective measures. Laboratory investigations into the biology of adolescent sleep have examined circadian rhythms, looking specifically at chronotype and social jet lag, phase preference, and sleepiness as measured by the Multiple Sleep Latency Test, the Maintenance of Wakefulness Test, and/or the Epworth Sleepiness Scale-Children. Longitudinal data on sleep/wake behavior is often estimated using actigraphy, sleep-wake diaries, and/or activity logs. Additional laboratory data providing more granular detail about circadian rhythms, such as measures of internal desynchrony and amplitude, transcriptomics/genomics, large-scale measurement of circadian physiology, and environmental light exposure, could still be valuable. Further measures of ultradian activity within sleep and correlation of these measures with other outcome covariates such as socioeconomic status, biological identity, and gender are still needed as well.

Refine and standardize outcome measures

Data regarding the outcome of school start time delays has largely been collected using academic measures in the form of grades earned, test results, and absences/tardies, as well as surveys of students, parents, and teachers, and self-report sleep diaries and actigraphically estimated sleep-wake patterns. How and when those entities gather such data, however, is not standardized, except within each school. Even a definition of what constitutes a "tardy," for example, can differ from building to building. For that reason, performance and behavioral data gathered from school, district, and state databases should be used with caution when conducting comparative analyses.

For performance data to be meaningful across schools, databases at the school, district, and state levels need to become more accurate and granular. For example, they might include student commute length, as well as the actual time of day mandatory classes start vs. any optional "zero-hour" period before the regular school day begins. However, even these attempts to create comparable databases may be inadequate for inherently subjective measures of academic success such as grades and test scores. Datasets such national health surveys (eg, the Youth Risk Behavior Survey), rates of drug use, mental health measures, youth employment, and car crash data from state departments of health or public safety are available to conduct cross-disciplinary analyses, but published literature to date suggests they remain underutilized.

Consider systems-level approaches

Qualitative data, such as upstream mechanisms/antecedents (eg, social determinants of health and policy determinants of health), are often overlooked or undervalued, even when strongly related to functional outcomes. Such data include interviews of students and other stakeholders, answers to open-ended survey questions, and documented review of district policies and meeting minutes. A

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systems-level approach (including these determinants, a wide range of stakeholders, and hypothesized outcomes) could provide a more in-depth understanding of whether qualitative and/or quantitative data are necessary to answer a given research question. A social-ecological framework to examine nested systems of individuals in households, and households in communities, may also provide a more nuanced understanding of the impact of school hours on commuting, childcare, family life, and extracurriculars, as well as their impact on elementary-school-aged children.

Facilitate interdisciplinary and policy-guided research

Leveraging the literature of sleep-dependent cognition to support academic achievement requires moving beyond laboratory studies to more policy-guided sleep interventions at the school or student level. The new California law offers a unique opportunity to create an educational neuroscience of sleep and disentangle the mechanisms of complex disorders by combining the tools of sleep science, cognitive neuroscience, and educational research.[138] The same techniques can be used to build on existing work exploring not only associations but also *why and how*. A key priority is identifying which educational outcomes (eg, grades, test scores, disciplinary referrals, mental health services, or quality of life) best reflect sleep-related changes in memory consolidation, attentional capacity, and emotional and motivational regulation.

Equally critical is designing studies uniting cognitive neuroscience with the theater of policy change. Despite best efforts to model classrooms,[139,140] laboratory studies do not adequately represent the dynamics of sleep in the schools or student populations they model. Remedying these limitations will require moving beyond small, controlled studies to examine large datasets from governmental or local agencies—and large-scale change, as in California—in new ways. Social media, low-cost wearables, and online data collection (eg, ecological momentary assessment of cognitive tasks, sleep diaries, attention, or mood) offer countless possibilities as well. Future studies of the impact of start time change should also consider more personalized profiles of student and community strengths and needs, including social, political, and economic milieu.

Creating these and other interdisciplinary opportunities for researchers whose work touches on sleep and school start time policy to share and review each other's work should facilitate evidence-based school and legislative policies going forward. As sleep researchers collaborate with experts in other fields, for example, education, juvenile justice, nursing, transportation, operations research, or school psychology, the depth of research related to sleep will grow and spur publication of sleep-related research in more journals and in fields beyond medicine and sleep health.

Expanding research on community impact

Proposed changes to school hours in any direction, later or earlier, potentially arouse concerns among community stakeholders about how changes may impact personal/family routines, sometimes producing pushback strong enough to disincentivize school leaders from implementing changes.[130,141] Indeed, many aspects of community life—including traffic patterns and safety, childcare, athletics and other extracurricular activities, after-school programs and classes, and student jobs—revolve around public school hours. Changes to public school hours thus potentially impact not just teachers, administrators, students, and families, but also athletic directors, bus drivers, childcare providers, commuters, and small businesses employing students.

While understandable, concerns about community impact are countered by experience from hundreds of schools that have delayed bell-times, as well as those that have always started class after 8:30 AM. These experiences consistently show that community life adjusts to school hours, not vice versa, and reveal a myriad of feasible and affordable ways to delay middle and high school class times. In fact, most fears and speculations about the impact of later start times on childcare, transportation costs, traffic, parental commutes, after-school jobs, and related aspects of community life have turned out to be overblown, temporary, or remediable with stakeholder input and creative thinking.[22,142] Even concerns about transportation and other costs often turn out to be unwarranted, with many communities finding ways to delay bell times at low or no cost, and sometimes with cost savings.[133,142-144] The growing number of school districts delaying bell times in California and beyond provides numerous opportunities to expand this knowledge base (Table 2).

Athletics, road safety, and other aspects of community life

In addition to evidence from hundreds of districts that have already delayed start times, additional detailed evidence regarding specific aspects of community life—including positive impacts on family interactions, injury prevention, and road safety—might help school communities address concerns that can underlie resistance to change. Already, for example, several districts, have confirmed that

Table 2
Recommendations for expanded research

Impact of school start times on preK-5th grade students
Associations of daylight-saving time with school start times and adolescent sleep
Impact of bus pick-up times and commute times on student sleep, health, and well-being
Relationship of later start times to student "wake up" times
Impact of later start times on economic and social disparities across communities
Impact of later start times on juvenile crime rates
Impact of later start times on athletic injuries and performance and recovery from injury, including concussions
Impact of school start time change in different seasons and locations within a time zone
Impact of delaying school start times on non-student stakeholders (eg, bus drivers, teachers, parents, and local businesses)
Upstream and downstream consequences of social determinates of health
Impact of classroom lighting on sleep and circadian timing
Impact of before-school instruction and activities on student sleep, health, and well-being
Impact of COVID-19-related schedule changes, including later, flexible, and virtual hours
Impact of school start times and pre-existing health conditions (eg, sleep disorders, ADHD, depression)
Consequences of later start times on behavioral measures of daytime sustained attention
Relationship between school start time and family life, including morning stress, family breakfasts, homework, and extracurricular activities
Gender differences in sleep time/wake time related to girls'/boys' helping routines with younger siblings, particularly with a view to cultural norms/expectations.
Time-use data such as changes in breakfast times or contrasting student alertness in morning vs. afternoon classes
Impact on risks, congestion, and safety for road users, including pedestrians, bicyclists, bus drivers/assistants, teachers, and other commuters.
Best change management practices for delaying school start times, including ways to reduce burdens on school systems and communities
Effects of later school start times on vulnerable populations, as well as means of implementation that reduce health and academic disparities
Educational outcomes (eg, grades, attendance, disciplinary action, special education or mental health services, quality of life, participation in extracurriculars, family/peer relations, or risk-taking behaviors) that best reflect underlying cognitive and affective brain systems regulated by sleep
Role of systemic and individual contributors to sleep health in optimizing benefits of later school start times
Understanding of the science of adolescent sleep and school start times among school stakeholders (eg, administrators, teachers, school boards, parents, coaches, etc.)
Relationship of sleep health education for adults to school start time change
Relationship of sleep health education to students' views of sleep and sleep behaviors

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after moving to later start times, the number of students participating in school athletic programs increases, or, if a team has no room to expand, stays the same, and many confirm winning records. Even more valuable would be quantifiable data, including number of games played, injuries reported, win-loss records, and duration of practices. In addition, while some evidence has already associated sleep loss in adolescents with increased sports-related and musculoskeletal injuries,[95] increased training time, and longer recovery time from acute injury,[145] outcome studies specifically looking at the impact of delaying bell times on these areas and of pre-screening for sleep health prior to athletic participation are still needed.

Other research needs include studies evaluating the impact of start time change on student commute times (urban and rural; public transportation, and district-provided transportation), differentiating the impact of school start time from bus pick-up and wake times, and addressing the association between bell times and pedestrian and bicycle fatalities (the largest growing areas of roadway fatalities), and on stakeholders including teachers, coaches, bus drivers, and other operations staff. The association between student sleep and homework load, online learning system hours and deadlines, and timing of athletic events and other extracurricular programming needs further exploration as well, as does the association between US university admissions and the prioritization of academic and extracurricular excellence over mental and physical health. Developing a suite of consensus items of outcomes for school start time change could help state and national data collection efforts, as could a public database of outcomes research.

Opportunities for healthy sleep

Later start times are a necessary, but not sufficient, condition for healthy adolescent sleep, and communities resistant to change, even if required to do so by law, may fall short of desired outcomes by continuing practices such as optional zero-hour classes or late-night sports and other extracurriculars. Social and family norms, and individual student behaviors, may interfere with healthy sleep habits and result in insufficient sleep regardless of school start times as well. As more communities move to later start times, these hypotheses should be examined empirically.

Conversely, additional research is needed to elucidate both systemic and individual factors that may optimize the opportunities for healthy sleep that later start times provide. These factors include sleep health education and interventions, scheduling of before- and after-school activities, and individual behaviors and sleep disorders. Extant research on sleep health education and preventive-intervention programs in sleep health, however, remains limited,[146-150] with significant gaps in issues such as developmental stage to begin education, who should deliver information, and target audiences, as well as optimal content, format, and style of teaching and intervention.

Any researcher developing and assessing sleep education and sleep health intervention programs for youth (and their families) should begin by considering strategies employed in sleep education in other populations including college students and students in the health professions,[151-157] as well as in other public health programs, such as smoking cessation and seat belt use.[158-160] Researchers developing and validating measures of program effectiveness both during the school years and/or beyond should also operationalize program variables such as knowledge about sleep and behavioral change in sleep patterns and habits. In all program development and testing, community-based participatory research (CBPR) including students, parents, and school administrators, and other stakeholders is essential. Because CBPR actively engages community stakeholder groups in data collection, with stakeholder ideas and feedback used to formulate survey and focus group questions, findings may be regarded by both community stakeholders and the research community as more credible and useful than data collected solely by outside researchers.

Sleep health disparities and differences

A recurrent theme of the summit involved the pressing need to acknowledge and attend to known sleep health disparities—including identifying socially just ways to build the political will required to establish and protect school hours compatible with adolescent sleep health.[130] Unfortunately, studies on delaying school start times to date have rarely investigated the implications for vulnerable youth. In particular, there is little research on differential effects of delaying school start times for families of different socioeconomic status or for homeless youth, youth of color, Native American youth, LGBTQ adolescents, youth in the foster care and juvenile justice system, special needs youth, single-parent households, and youth from families with mental illness.

Future research needs to consider the short- and longer-term effects of delayed school start times on these and other vulnerable populations. In addition, it must identify why different households might have different experiences with school start times and how different sleep health belief systems might contribute to the operationalization of start time changes. Ultimately, we need to identify implementation characteristics of school start time change that maximize sleep benefits for vulnerable youth, with a parallel process of mitigating sleep deficiency while addressing other health disparities. This broad research agenda will require both qualitative and quantitative studies, ideally longitudinal, and collaborative across the full spectrum of stakeholders.

Translating research

Summit participants stressed the continuing challenges in communicating interdisciplinary research to a diverse stakeholder base and in translating that research into public policy. Critical to effective translation, and a high research priority, is implementation science research aimed at better defining best change management practices. Equally critical is effective communication of data-based research about the association between sleep and school start times, the public health and safety benefits of school hours conducive to healthy sleep, and the feasibility of delaying bell times with minimal burden to school communities.

Change management and logistics

While there is no one-size-fits-all schedule or formula to successful bell-time change, many communities that have successfully delayed bell times share definable characteristics. These include strong school leadership supporting change, recognition that perceived challenges are usually worse in anticipation than in reality, authentic stakeholder engagement, community education about adolescent sleep health, and adequate adjustment periods.[142] Two distinct patterns have emerged among districts implementing later start times successfully: top-down and iterative. Some district leaders simply announce a schedule change and implement it without fanfare. Others explain the benefits to the community and promote healthy schedules like any other large-scale school division change, including the series of decisions decades ago to move to earlier bell times. However, many districts, particularly those in which delaying start times has become a highly visible and contentious issue, require an iterative process to build consensus and political will, often involving multi-year efforts to educate and facilitate conversation among all community stakeholders.[161-165]

Experiences during the COVID-19 pandemic may have accelerated the change process. Growing concern about the profound and enduring consequences of adolescent mental and behavioral health problems, heightened by social isolation and virtual schooling, energized communities to seek evidence-based, population-level interventions to improve adolescent sleep, health, and well-being, including later school start times. Innovative and rapidly changing instructional

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scenarios during the ongoing COVID-19 pandemic offer unprecedented opportunities to study the impact of later hours in the context of flexible and/or virtual school schedules. Indeed, several surveys conducted during the pandemic have already associated virtual classes starting at 8:30 AM or later with more sleep, improved mental health, and greater academic engagement, and Start School Later has documented dozens of districts that plan to maintain, or that are considering maintaining, these later schedules as in-person classes resume.[165-173]

One pressing research need involves comparing top-down to iterative, district-level change processes. On the surface, statewide policies appear to be more equitable, ensuring that students' ability to get healthy sleep will not vary by zip code. State and regional policies also appear to be more efficient by allowing for coordinated transportation, athletic, and other inter-district schedules. At the same time, the iterative, consensus-building process often required for district-level change may be more effective in creating community support and in building an awareness to optimize the opportunity for healthy sleep that delayed bell times create. The California legislation provides an opportunity to explore some of these questions, including the impact of broad statewide standards on individual community-based policies and implementation practices.

Finally, more research is needed to develop a better understanding of community resistance to change, including work to identify major stakeholders in school start time decisions, develop a standardized needs assessment tool to quantify stakeholder perceptions, and define outcomes that most influence decision-making.[142] Such work should include elucidating the way social norms about sleep and student success contribute to student sleep insufficiency and/or drive community resistance. Studying how principles of behavioral economics might be applied to facilitate change could be valuable as well.[174] In addition, we need to identify ways to ensure developmentally appropriate school schedules times that minimize costs and burdens to school communities.

Communicating science to stakeholders

The ability of researchers to communicate evidence about sleep and school start times to the press, policymakers, and the public at large is critical to stakeholder acceptance of inherently disruptive schedule changes. A major challenge, however, is the decentralization of education in the United States, coupled with the wide variety of research disciplines and broad spectrum of the community involved in bell-time change.

At present many researchers, including those informing the media and policymakers, remain unaware of findings and/or accepted methodology and standards of evidence in fields beyond their own. In a policy arena that relies on research from a wide variety of disciplines, it is critical for researchers to interface with the body of evidence outside their own discipline. Presenting an accurate and complete picture of existing evidence in a policy context may require collaboration with scholars in other disciplines, particularly because all relevant studies may not appear in disciplined-based literature reviews and databases. Sleep researchers collecting data within a school setting might thus consider collaborating with educators and education policy researchers who understand the variations in school-system data collection practices. Similarly, they might consult with experts in operations research to understand transportation parameters and metrics, or how communities delaying start times have rearranged sports practices or childcare to meet the needs of coaches, students, teachers, and families. Equally important is holding these and other issues outside a particular researcher's area of expertise to the same level of scrutiny required of statements in one's own discipline rather than including them in research papers as unreferenced assumptions.

Other challenges arise when community members and policymakers read and interpret studies that researchers may have intended for colleagues, a frequent occurrence when research has bearing on public policy. Scientists appreciate nuance and focus on methodology, context, and complexity, whereas policymakers prefer simplicity and certainty.[164] In an age of social media, even peer-reviewed publications are easily accessed and shared by policymakers and members of the public, who may have little grounding in statistical or methodological analysis of research studies. Lay readers may lack background to contextualize a given study or piece of data or may be scanning studies for a specific sentence to advance an advocacy agenda.[164]

Of particular concern are statements identifying gaps and caveats about research, which however accurate or appropriate among colleagues, risk being misinterpreted and/or taken out of context in the public policy arena. Even statements about a need for additional study can evoke doubt in the non-scientific community about making evidence-based policy changes, regardless of the consensus of the research community.[164,175-179] For these reasons, researchers whose work touches on public policy must take special care even in peer-reviewed papers and other communications intended for colleagues to avoid language that might be misconstrued or misrepresented by policymakers, especially given that once a misuse or misinterpretation is shared digitally, it is difficult if not impossible to eradicate.[164,180-182] Direct efforts to disseminate research to lawmakers, school leaders, and school communities present additional challenges, requiring plain, jargon-free language to make complex ideas clear and accessible.

Conclusion

Effectively translating adolescent sleep and school start time research into policy will require a multidisciplinary effort. A top priority is implementation science research to identify the most effective ways to build school health policies that support student sleep, as well as educate the wider school community, in ways that reduce disparities. This includes research to identify implementation practices that build community support for proven public health policies such as middle and high school start times after 8:30 AM, which have been shown to improve adolescent sleep, health, safety, and learning. Community-engaged sleep research in a wide variety of disciplines will also be required to support school and community leaders and help them develop school and workplace policies that support the basic human right for sleep for all stakeholders.

Already clear is the need for and feasibility of operating schools at times that allow adolescents an opportunity for healthy sleep. If the COVID-19 pandemic has taught us anything, it is that schools can and do make massive systemic changes when they prioritize public health. Countless communities around the world forced to adopt virtual schooling almost overnight have discovered latent flexibility and adaptability, as well as new ways to think about schedules, lifestyles, and schooling. Their experiences with remote learning and mixed, flexible schedules may become key components in school start time outcomes research and planning. In addition, by opening minds to global perspectives on the many ways to run schools, these experiences have spurred new thinking about schedules, lives, and schooling and confirmed the possibility of change previously deemed infeasible or unimaginable.

Declaration of conflict of interest

Dr. Pelayo reports grants from the American Academy of Sleep Medicine, and from the National Sleep Foundation during the conduct of the study; he also served on the boards of the nonprofit organizations Start School Later and the National Sleep Foundation

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and volunteered as chair of the American Academy of Sleep Medicine's Political Action Committee. Drs. Carskadon, Saletin, Troxel, Owens, Rubens, Wahlstrom, and Keller have nothing to disclose. Dr. Hale reports personal fees from National Sleep Foundation, outside the submitted work and serves as Chair of the Board of Directors of the National Sleep Foundation (volunteer position). Ms. Payne reports receiving an honorarium (speaker's fee) from Stanford University School of Medicine's Department of Psychiatry and Behavioral Sciences. Dr. Ziporyn reports personal fees from Stanford University School of Medicine for editorial services. Dr. Wolfson reports personal fees from Stanford University School of Medicine for speaking at Summit referred to in this paper.

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Appendix

Chairs and speakers in the Summit on Adolescent Sleep and School Start Times, held virtually on January 22-23, 2021 in memory of William C. Dement, MD and Mark W. Mahowald, MD, were the following:

Co-Chairs

Judith Owens, MD, MPH, Harvard Medical School and Boston Children's Hospital

Rafael Pelayo, MD, Stanford University School of Medicine

Kyla Wahlstrom, PhD, University of Minnesota

Amy R. Wolfson, PhD, Loyola University Maryland

Honorary Chairs

Mary A. Carskadon, PhD, Alpert Medical School of Brown University

William C. Dement, MD, PhD, Stanford University School of Medicine

Planning Committee

Ann Gallagher, MS, Start School Later

Irena Keller, PhD, Las Positas College

Phyllis Payne, MPH, Sleep in Fairfax and Start School Later

Sonia Rubens, PhD, Santa Clara University

Terra Ziporyn, PhD, Start School Later

Speakers

Kevin C. Bastian, PhD, UNC Chapel Hill

Ashura Williams Buckley, MD, The National Institutes of Health

Orfeu M. Buxton, PhD, Pennsylvania State University

Mary A. Carskadon, PhD, Alpert Medical School of Brown University

Stephanie Crowley, PhD, Rush University Medical Center

Ann Gallagher, MS, Start School Later/Healthy Hours

Lauren Hale, PhD, Stony Brook University

Deborah Hersman, MS, National Transportation Safety Board

Clete A. Kushida, MD, PhD, FAASM, Stanford University School of Medicine

Shane R. Jimerson, PhD, NCSP, University of California, Santa Barbara

Irena Keller, PhD, Las Positas College

Lisa J. Meltzer, PhD, BCSM, National Jewish Health

Judith Owens, MD, MPH, Harvard Medical School and Boston Children's Hospital

Phyllis Payne, MPH, Sleep in Fairfax and Start School Later/Healthy Hours

Rafael Pelayo, MD, FAASM, Stanford University School of Medicine

Mark R. Rosekind, PhD, Zoox

Sonia Rubens, PhD, Santa Clara University

Jared M. Saletin, PhD, Alpert Medical School of Brown University

Azizi Seixas, PhD, NYU Langone Health

Wendy Troxel, PhD, RAND Corporation

Kyla Wahlstrom, PhD, University of Minnesota

Rachel Widome, PhD, University of Minnesota

Amy R. Wolfson, PhD, Loyola University Maryland

Terra Ziporyn, PhD, Start School Later/Healthy Hours

References

1. Stanford Medicine. Summit on Adolescent Sleep and School Start Times: Setting the Research Agenda for California and Beyond. 2021; Available at: https://med.stanford.edu/psychiatry/education/training/sleep.html. Accessed July 7, 2021.
2. Troxel WM, Wolfson AR. The intersection between sleep science and policy: introduction to the special issue on school start times. *Sleep Health*. 2017;3(6):419–422.
3. Carskadon MA. Patterns of sleep and sleepiness in adolescents. *Pediatrician*. 1990;17(1):5–12.
4. Carskadon MA, Harvey K, Dement WC. Sleep loss in young adolescents. *Sleep*. 1981;4(3):299–312.
5. Carskadon MA, Harvey K, Duke P, Anders TF, Litt IF, Dement WC. Pubertal changes in daytime sleepiness. *Sleep*. 1980;2(4):453–460.
6. Carskadon MA, Vieira C, Acebo C. Association between puberty and delayed phase preference. *Sleep*. 1993;16(3):258–262.
7. Andrade MM, Benedito-Silva AA, Menna-Barreto L. Correlations between morningness-eveningness character, sleep habits and temperature rhythm in adolescents. *Braz J Med Biol Res*. 1992;25(8):835–839.
8. Ishihara K, Honma Y, Miyake S. Investigation of the children's version of the morningness-eveningness questionnaire with primary and junior high school pupils in Japan. *Percept Motor Skills*. 1990;71(3_suppl):1353–1354.
9. Strauch I, Meier B. Sleep need in adolescents: a longitudinal approach. *Sleep*. 1988;11(4):378–386.
10. Zuckerman D. *Early Morning Classes, Sleepy Students and Risky Behaviors*. National Center for Health Research; 2015. https://www.center4research.org/early-morning-classes-sleepy-students-risky-behaviors/.
11. Wolfson AR, Carskadon MA. A survey of factors influencing high school start times. *NASSP Bull*. 2005;89(642):47–66.
12. Basch CE, Basch CH, Ruggles KV, Rajan S. Prevalence of sleep duration on an average school night among 4 nationally representative successive samples of American high school students, 2007-2013. *Prev Chronic Dis*. 2014;11:E216.
13. Drobnich D. A National Sleep Foundation's conference summary: the National Summit to Prevent Drowsy Driving and a new call to action. *Ind Health*. 2005;43(1):197–200.
14. Sawyer H, Taie S. *Start Time for US Public High Schools. Data Point. NCES 2020-006*. National Center for Education Statistics; 2020.
15. Taie S, Goldring R. *Characteristics of Public Elementary and Secondary School Principals in the United States: Results From the 2015-16 National Teacher and Principal Survey. First Look*. National Center for Education Statistics; 2017. NCES 2017-070.
16. Wahlstrom K. Changing times: findings from the first longitudinal study of later high school start times. *NASSP Bull*. 2002;86(633):3–21.
17. Wolfson AR, Ziporyn TD. Adolescence and emerging adulthood. In: Montgomery-Downs H, ed. *Sleep Science*. Oxford: Oxford University Press; 2020.
18. Wolfson AR, Carskadon MA. Sleep schedules and daytime functioning in adolescents. *Child Dev*. 1998;69(4):875–887.
19. Carskadon MA, Wolfson AR, Acebo C, Tzischinsky O, Seifer R. Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days. *Sleep*. 1998;21(8):871–881.
20. Start School Later. Position statements and resolutions on sleep and school start times. Available at: https://www.startschoollater.net/position-statements.html. Accessed July 24, 2021.
21. Start School Later. Research and Health Experts Support SB 328 2019; Available at: https://www.startschoollater.net/uploads/9/7/9/6/9796500/consensus_letter_for_research_health_medical_experts_sb328_090919.pdf. Accessed October 16, 2019.

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22. Advisory Committee on Later School Start Times at Secondary Schools. Sleep deprivation in adolescents: the case for delaying secondary school start times. 2019; Available at: http://jsg.legis.state.pa.us/resources/documents/ftp/publications/2019-10-17%20SSSTweb.PDF. Accessed November 15, 2019.
23. Borbely AA. A two process model of sleep regulation. *Hum Neurobiol*. 1982;1(3):195–204.
24. Hagenauer MH, Perryman JI, Lee TM, Carskadon MA. Adolescent changes in the homeostatic and circadian regulation of sleep. *Dev Neurosci*. 2009;31(4):276–284.
25. Melo PR, Goncalves BS, Menezes AA, Azevedo CV. Circadian activity rhythm in pre-pubertal and pubertal marmosets (Callithrix jacchus) living in family groups. *Physiol Behav*. 2016;155:242–249.
26. Carskadon MA. Sleep in adolescents: the perfect storm. *Pediatr Clin North Am*. 2011;58(3):637–647.
27. Jenni OG, Achermann P, Carskadon MA. Homeostatic sleep regulation in adolescents. *Sleep*. 2005;28(11):1446–1454.
28. Jenni OG, Carskadon MA. Spectral analysis of the sleep electroencephalogram during adolescence. *Sleep*. 2004;27(4):774–783.
29. Paruthi S, Brooks LJ, D'Ambrosio C, et al. Recommended amount of sleep for pediatric populations: a consensus statement of the American Academy of Sleep Medicine. *J Clin Sleep Med*. 2016;12(6):785–786.
30. Hirshkowitz M, Whiton K, Albert SM, et al. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. *Sleep Health*. 2015;1(1):40–43.
31. Keyes KM, Maslowsky J, Hamilton A, Schulenberg J. The great sleep recession: changes in sleep duration among US adolescents, 1991-2012. *Pediatrics*. 2015;135(3):460–468.
32. Wheaton AG, Jones SE, Cooper AC, Croft JB. Short sleep duration among middle school and high school students - United States, 2015. *MMWR Morb Mortal Wkly Rep*. 2018;67(3):85–90.
33. Guglielmo D, Gazmararian JA, Chung J, Rogers AE, Hale L. Racial/ethnic sleep disparities in US school-aged children and adolescents: a review of the literature. *Sleep Health*. 2018;4(1):68–80.
34. James S, Chang AM, Buxton OM, Hale L. Disparities in adolescent sleep health by sex and ethnoracial group. *SSM Popul Health*. 2020;11: 100581.
35. Dunbar M, Mirpuri S, Yip T. Ethnic/racial discrimination moderates the effect of sleep quality on school engagement across high school. *Cultur Divers Ethnic Minor Psychol*. 2017;23(4):527–540.
36. Marco CA, Wolfson AR, Sparling M, Azuaje A. Family socioeconomic status and sleep patterns of young adolescents. *Behav Sleep Med*. 2011;10(1):70–80.
37. Matthews KA, Hall M, Dahl RE. Sleep in healthy black and white adolescents. *Pediatrics*. 2014;133(5):e1189–e1196.
38. Majeno A, Tsai KM, Huynh VW, McCreath H, Fuligni AJ. Discrimination and sleep difficulties during adolescence: The mediating roles of loneliness and perceived stress. *J Youth Adolesc*. 2018;47(1):135–147.
39. Wang Y, Yip T. Sleep facilitates coping: moderated mediation of daily sleep, ethnic/racial discrimination, stress responses, and adolescent well-being. *Child Dev*. 2020;91(4):e833–e852.
40. Cunningham RM, Walton MA, Carter PM. The Major Causes of Death in Children and Adolescents in the United States. *N Engl J Med*. 2018;379(25):2468–2475.
41. Steinberg L. A social neuroscience perspective on adolescent risk-taking. *Dev Rev*. 2008;28(1):78–106.
42. Suleiman AB, Dahl RE. Leveraging neuroscience to inform adolescent health: the need for an innovative transdisciplinary developmental science of adolescence. *J Adolesc Health*. 2017;60(3):240–248.
43. Kessler RC, Chiu WT, Demler O, Merikangas KR, Walters EE. Prevalence, severity, and comorbidity of 12-month DSM-IV disorders in the National Comorbidity Survey Replication. *Arch Gen Psychiatry*. 2005;62(6):617–627.
44. Johnston LD, O'Malley PM, Bachman JG, Schulenberg JE, Miech RA. *Monitoring the Future national survey results on drug use, 1975-2014: Volume II, college students and adults ages 19-55*. Ann Arbor, MI: Institute for Social Research, University of Michigan; 2015.
45. D'Amico EJ, Tucker JS, Miles JN, Ewing BA, Shih RA, Pedersen ER. Alcohol and marijuana use trajectories in a diverse longitudinal sample of adolescents: examining use patterns from age 11 to 17 years. *Addiction*. 2016;111(10):1825–1835.
46. Harris LM, Huang X, Linthicum KP, Bryen CP, Ribeiro JD. Sleep disturbances as risk factors for suicidal thoughts and behaviours: a meta-analysis of longitudinal studies. *Sci Rep*. 2020;10(1):1–11.
47. Winsler A, Deutsch A, Vorona RD, Payne PA, Szklo-Coxe M. Sleepless in Fairfax: the difference one more hour of sleep can make for teen hopelessness, suicidal ideation, and substance use. *J Youth Adolesc*. 2015;44(2):362–378.
48. Baum KT, Desai A, Field J, Miller LE, Rausch J, Beebe DW. Sleep restriction worsens mood and emotion regulation in adolescents. *J Child Psychol Psychiatry*. 2014;55(2):180–190.
49. Dahl RE. Adolescent brain development: a period of vulnerabilities and opportunities. Keynote address. *Ann N Y Acad Sci*. 2004;1021(1):1–22.
50. Pasch KE, Latimer LA, Cance JD, Moe SG, Lytle LA. Longitudinal bi-directional relationships between sleep and youth substance use. *J Youth Adolesc*. 2012;41(9):1184–1196.
51. Hasler BP, Bruce S, Scharf D, Ngari W, Clark DB. Circadian misalignment and weekend alcohol use in late adolescent drinkers: preliminary evidence. *Chronobiol Int*. 2019;36(6):796–810.
52. Hasler BP, Clark DB. Circadian misalignment, reward-related brain function, and adolescent alcohol involvement. *Alcohol Clin Exp Res*. 2013;37(4):558–565.
53. Hasler BP, Franzen PL, de Zambotti M, et al. Eveningness and later sleep timing are associated with greater risk for alcohol and marijuana use in adolescence: initial findings from the national consortium on alcohol and neurodevelopment in adolescence study. *Alcohol Clin Exp Res*. 2017;41(6):1154–1165.
54. Weaver MD, Barger LK, Malone SK, Anderson LS, Klerman EB. Dose-dependent associations between sleep duration and unsafe behaviors among us high school students. *JAMA Pediatr*. 2018;172(12):1187–1189.
55. Womack S, Hook J, Reyna S, Ramos M. Sleep loss and risk-taking behavior: a review of the literature. *Behav Sleep Med*. 2013;11(5):343–359.
56. Wong MM, Roberson G, Dyson R. Prospective relationship between poor sleep and substance-related problems in a national sample of adolescents. *Alcohol Clin Exp Res*. 2015;39(2):355–362.
57. Clarke G, Harvey AG. The complex role of sleep in adolescent depression. *Child Adolesc Psychiatr Clin*. 2012;21(2):385–400.
58. Troxel WM, Rodriguez A, Seelam R, Tucker JS, Shih RA, D'Amico EJ. Associations of longitudinal sleep trajectories with risky sexual behavior during late adolescence. *Health Psychol*. 2019;38(8):716.
59. Hasler G, Buysse DJ, Klaghofer R, et al. The association between short sleep duration and obesity in young adults: a 13-year prospective study. *Sleep*. 2004;27(4):661–666.
60. Hasler BP, Kirisci L, Clark DB. Restless sleep and variable sleep timing during late childhood accelerate the onset of alcohol and drug involvement. *J Stud Alcohol Drugs*. 2016;77(4):649–655.
61. Wong MM, Brower KJ, Zucker RA. Childhood sleep problems, early onset of substance use and behavioral problems in adolescence. *Sleep Med*. 2009;10(7):787–796.
62. Walker DM, Bell MR, Flores C, Gulley JM, Willing J, Paul MJ. Adolescence and reward: making sense of neural and behavioral changes amid the chaos. *J Neurosci*. 2017;37(45):10855–10866.
63. Walker WH, Walton JC, DeVries AC, Nelson RJ. Circadian rhythm disruption and mental health. *Transl Psychiatry*. 2020;10(1):28.
64. Hasler BP, Pedersen SL. Sleep and circadian risk factors for alcohol problems: a brief overview and proposed mechanisms. *Curr Opin Psychol*. 2019;34:57–62.
65. Dahl RE. The regulation of sleep and arousal: Development and psychopathology. *Dev Psychopathol*. 1996;8:3–27.
66. McMakin DL, Dahl RE, Buysse DJ, et al. The impact of experimental sleep restriction on affective functioning in social and nonsocial contexts among adolescents. *J Child Psychol Psychiatry*. 2016;57(9):1027–1037.
67. Lo JC, Lee SM, Teo LM, Lim J, Gooley JJ, Chee MWL. Neurobehavioral impact of successive cycles of sleep restriction with and without naps in adolescents. *Sleep*. 2017;40(2):zsw042. https://doi.org/10.1093/sleep/zsw042.
68. Tempesta D, Socci V, De Gennaro L, Ferrara M. Sleep and emotional processing. *Sleep Med Rev*. 2018;40:183–195.
69. Walker MP, van der Helm E. Overnight therapy? The role of sleep in emotional brain processing. *Psychol Bull*. 2009;135(5):731–748.
70. Owens J, Adolescent Sleep Working G, Committee on A. Insufficient sleep in adolescents and young adults: an update on causes and consequences. *Pediatrics*. 2014;134(3):e921–e932.
71. Orzech KM, Acebo C, Seifer R, Barker D, Carskadon MA. Sleep patterns are associated with common illness in adolescents. *J Sleep Res*. 2014;23(2):133–142.
72. Shochat T, Cohen-Zion M, Tzischinsky O. Functional consequences of inadequate sleep in adolescents: a systematic review. *Sleep Med Rev*. 2014;18(1):75–87.
73. Arora T, Taheri S. Associations among late chronotype, body mass index and dietary behaviors in young adolescents. *Int J Obes (Lond)*. 2015;39(1):39–44.
74. Beebe DW, Simon S, Summer S, Hemmer S, Strotman D, Dolan LM. Dietary intake following experimentally restricted sleep in adolescents. *Sleep*. 2013;36(6):827–834.
75. Roenneberg T, Allebrandt KV, Merrow M, Vetter C. Social jetlag and obesity. *Curr Biol*. 2012;22(10):939–943.
76. Cespedes Feliciano EM, Quante M, Rifas-Shiman SL, Redline S, Oken E, Taveras EM. Objective sleep characteristics and cardiometabolic health in young adolescents. *Pediatrics*. 2018;142(1):e20174085.
77. Countryman AJ, Saab PG, Llabre MM, Penedo FJ, McCalla JR, Schneiderman N. Cardiometabolic risk in adolescents: associations with physical activity, fitness, and sleep. *Ann Behav Med*. 2013;45(1):121–131.
78. Klingenberg L, Chaput JP, Holmback U, et al. Acute sleep restriction reduces insulin sensitivity in adolescent boys. *Sleep*. 2013;36(7):1085–1090.
79. Besedovsky L, Lange T, Haack M. The sleep-immune crosstalk in health and disease. *Physiol Rev*. 2019;99(3):1325–1380.
80. Imeri L, Opp MR. How (and why) the immune system makes us sleep. *Nat Rev Neurosci*. 2009;10(3):199–210.
81. Cohen S, Doyle WJ, Alper CM, Janicki-Deverts D, Turner RB. Sleep habits and susceptibility to the common cold. *Arch Intern Med*. 2009;169(1):62–67.
82. Prather AA, Hall M, Fury JM, et al. Sleep and antibody response to hepatitis B vaccination. *Sleep*. 2012;35(8):1063–1069.
83. Evans S, Djilas V, Seidman LC, Zeltzer LK, Tsao JCI. Sleep quality, affect, pain, and disability in children with chronic pain: is affect a mediator or moderator? *J Pain*. 2017;18(9):1087–1095.
84. Control CfD, Prevention. *WISQARS (Web-based Injury Statistics Query and Reporting System)*. US Department of Health and Human Services; 2012.
85. Owens JA, Dearth-Wesley T, Herman AN, Whitaker RC. Drowsy driving, sleep duration, and chronotype in adolescents. *J Pediatr*. 2019;205:224–229.
86. Danner F, Phillips B. Adolescent sleep, school start times, and teen motor vehicle crashes. *J Clin Sleep Med*. 2008;4(6):533–535.

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87. Vorona RD, Szklo-Coxe M, Lamichhane R, Ware JC, McNallen A, Leszczyszyn D. Adolescent crash rates and school start times in two central Virginia counties, 2009-2011: a follow-up study to a southeastern Virginia study, 2007-2008. *J Clin Sleep Med*. 2014;10(11):1169–1177.
88. Vorona RD, Szklo-Coxe M, Wu A, Dubik M, Zhao Y, Ware JC. Dissimilar teen crash rates in two neighboring southeastern Virginia cities with different high school start times. *J Clin Sleep Med*. 2011;7(2):145–151.
89. Bin-Hasan S, Kapur K, Rakesh K, Owens J. School start time change and motor vehicle crashes in adolescent drivers. *J Clin Sleep Med*. 2020;16(3):371–376.
90. Wahlstrom K, Dretzke B, Gordon M, Peterson K, Edwards K, Gdula J. Examining the impact of later high school start times on the health and academic performance of high school students: a multi-site study. Retrieved from the University of Minnesota Digital Conservancy. 2014; https://conservancy.umn.edu/handle/11299/162769.
91. Meltzer L, Rizvi S, Chapman J. 634 impact of changing school start times on drowsy driving and teen motor vehicle crashes: a longitudinal examination. *Sleep*. 2021;44(suppl_2):A248–A249.
92. Davis AL, Avis KT, Schwebel DC. The effects of acute sleep restriction on adolescents' pedestrian safety in a virtual environment. *J Adolesc Health*. 2013;53(6):785–790.
93. Graves JM, Miller ME. Reduced sleep duration and history of work-related injuries among Washington State adolescents with a history of working. *Am J Ind Med*. 2015;58(4):464–471.
94. Milewski MD, McCracken CM, Meehan B, Stracciolini A. Increased hours of training per week is associated with decreased sleep in pediatric & adolescent athletes. *Orthop J Sports Med*. 2019;7(3_suppl). https://doi.org/10.1177/2325967119S00128.
95. Milewski MD, Skaggs DL, Bishop GA, et al. Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. *J Pediatr Orthop*. 2014;34(2):129–133.
96. Chau K. Impact of sleep difficulty on single and repeated injuries in adolescents. *Accid Anal Prev*. 2015;81:86–95.
97. Wheaton AG, Olsen EO, Miller GF, Croft JB. Sleep Duration and injury-related risk behaviors among high school students—United States, 2007-2013. *MMWR Morb Mortal Wkly Rep*. 2016;65(13):337–341.
98. Wickwire EM, Schnyer DM, Germain A, et al. Sleep, sleep disorders, and circadian health following mild traumatic brain injury in adults: review and research agenda. *J Neurotrauma*. 2018;35(22):2615–2631.
99. Carskadon MA. Sleep's effects on cognition and learning in adolescence. *Prog Brain Res*. 2011;190:137–143.
100. Fallone G, Acebo C, Arnedt JT, Seifer R, Carskadon MA. Effects of acute sleep restriction on behavior, sustained attention, and response inhibition in children. *Percept Mot Skills*. 2001;93(1):213–229.
101. Tonetti L, Fabbri M, Filardi M, Martoni M, Natale V. Effects of sleep timing, sleep quality and sleep duration on school achievement in adolescents. *Sleep Med*. 2015;16(8):936–940.
102. Curcio G, Ferrara M, De Gennaro L. Sleep loss, learning capacity and academic performance. *Sleep Med Rev*. 2006;10(5):323–337.
103. Dewald JF, Meijer AM, Oort FJ, Kerkhof GA, Bogels SM. The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: a meta-analytic review. *Sleep Med Rev*. 2010;14(3):179–189.
104. Abraham J, Scaria J. Influence of sleep in academic performance—an integrated review of literature. *J Nurs Health Sci*. 2015;4(4):78–81.
105. Walker MP. Cognitive consequences of sleep and sleep loss. *Sleep Med*. 2008;9(suppl 1):S29–S34.
106. Walker MP. Sleep-dependent memory processing. *Harv Rev Psychiatry*. 2008;16(5):287–298.
107. Smarr BL, Schirmer AE. 3.4 million real-world learning management system logins reveal the majority of students experience social jet lag correlated with decreased performance. *Sci Rep*. 2018;8(1):4793.
108. Groen JA, Pabilonia SW. Snooze or lose: High school start times and academic achievement. *Econ Educ Rev*. 2019;72:204–218.
109. Heissel JA, Norris S. Rise and shine the effect of school start times on academic performance from childhood through puberty. *J Hum Resour*. 2018;53(4):957–992.
110. Edwards F. Early to rise? The effect of daily start times on academic performance. *Econ Educ Rev*. 2012;31(6):970–983.
111. Phillips AJK, Clerx WM, O'Brien CS, et al. Irregular sleep/wake patterns are associated with poorer academic performance and delayed circadian and sleep/wake timing. *Sci Rep*. 2017;7(1):3216.
112. Wolfson AR, Spaulding NL, Dandrow C, Baroni EM. Middle school start times: the importance of a good night's sleep for young adolescents. *Behav Sleep Med*. 2007;5(3):194–209.
113. Alfonsi V, Palmizio R, Rubino A, et al. The association between school start time and sleep duration, sustained attention, and academic performance. *Nat Sci Sleep*. 2020;12:1161.
114. Lenard M, Morrill MS, Westall J. High school start times and student achievement: Looking beyond test scores. *Econ Educ Rev*. 2020;76: 101975.
115. Hysing M, Haugland S, Stormark KM, Bøe T, Sivertsen B. Sleep and school attendance in adolescence: results from a large population-based study. *Scand J Public Health*. 2015;43(1):2–9.
116. Preckel F, Lipnevich AA, Boehme K, et al. Morningness-eveningness and educational outcomes: The lark has an advantage over the owl at high school. *British Journal of Educational Psychology*. 2013;83(1):114–134.
117. Goldin AP, Sigman M, Braier G, Golombek DA, Leone MJ. Interplay of chronotype and school timing predicts school performance. *Nat Hum Behav*. 2020;4(4):387–396.
118. Goldstein D, Hahn CS, Hasher L, Wiprzycka UJ, Zelazo PD. Time of day, intellectual performance, and behavioral problems in morning versus evening type adolescents: Is there a synchrony effect? *Personal Individ Differ*. 2007;42(3):431–440.
119. Nahmod NG, Lee S, Master L, Chang AM, Hale L, Buxton OM. Later high school start times associated with longer actigraphic sleep duration in adolescents. *Sleep*. 2019;42(2):zsy212.
120. Gariepy G, Janssen I, Sentenac M, Elgar FJ. School start time and sleep in Canadian adolescents. *J Sleep Res*. 2017;26(2):195–201.
121. Widome R, Berger AT, Iber C, Wahlstrom K, Laska M, Kilian G, et al. Association of delaying school start time with sleep duration, timing, and quality among adolescents. *JAMA Pediatr*. 2020;174(7):697–704.
122. Lo JC, Lee SM, Lee XK, et al. Sustained benefits of delaying school start time on adolescent sleep and well-being. *Sleep*. 2018;41(6):zsy052.
123. Owens JA, Belon K, Moss P. Impact of delaying school start time on adolescent sleep, mood, and behavior. *Arch Pediatr Adolesc Med*. 2010;164(7):608–614.
124. Dunster GP, de la Iglesia L, Ben-Hamo M, et al. Sleepmore in Seattle: Later school start times are associated with more sleep and better performance in high school students. *Sci Adv*. 2018;4(12):eaau6200.
125. Alfonsi V, Scarpelli S, D'Atri A, Stella G, De Gennaro L. Later school start time: the impact of sleep on academic performance and health in the adolescent population. *Int J Environ Res Public Health*. 2020;17(7):2574.
126. Nahmod NG, Lee S, Buxton OM, Chang AM, Hale L. High school start times after 8:30 am are associated with later wake times and longer time in bed among teens in a national urban cohort study. *Sleep Health*. 2017;3(6):444–450.
127. Bowers JM, Moyer A. Effects of school start time on students' sleep duration, daytime sleepiness, and attendance: a meta-analysis. *Sleep Health*. 2017;3(6):423–431.
128. Neuroth LM, Ma M, Brooks-Russell A, Zhu M. The relationship of school start times, sleep duration and mental health among a representative sample of high school students in Colorado, 2019. *Int J Environ Res Public Health*. 2021;18(11):5708.
129. Wheaton AG, Chapman DP, Croft JB. School start times, sleep, behavioral, health, and academic outcomes: a review of the literature. *J Sch Health*. 2016;86(5):363–381.
130. Wolfson AR, Ziporyn T. Adolescent sleep and later school start times. In: Cappuccio FP, Miller MA, Lockley SW, eds. *Sleep, Health, and Society—From Aetiology to Public Health*. 2nd ed Oxford: Oxford University Press; 2018:215–223.
131. McKeever PM, Clark L. Delayed high school start times later than 8:30am and impact on graduation rates and attendance rates. *Sleep Health*. 2017;3(2):119–125.
132. Bastian KC, Fuller SC. Answering the bell: high school start times and student academic outcomes. *AERA Open*. 2018;4(4). https://doi.org/10.1177/2332858418812424.
133. Hafner M, Stepanek M, Troxel WM. The economic implications of later school start times in the United States. *Sleep Health*. 2017;3(6):451–457.
134. Shapiro TM. *The Educational Effects of School Start Times*. IZA World of Labor; 2015.
135. Carrell SE, Maghakian T, West JE. A's from Zzzz's? The causal effect of school start time on the academic achievement of adolescents. *Am Econ J Econ Policy*. 2011;3(3):62–81.
136. Jacob BA, Rockoff JE. *Organizing Schools to Improve Student Achievement: Start Times, Grade Configurations, and Teacher Assignments*. Washington, DC: Brookings Institution; 2011. Hamilton Project.
137. Illingworth G, Sharman R, Jowett A, Harvey CJ, Foster RG, Espie CA. Challenges in implementing and assessing outcomes of school start time change in the UK: experience of the Oxford Teensleep study. *Sleep Med*. 2019;60:89–95.
138. Manoach DS, Stickgold R. Abnormal sleep spindles, memory consolidation, and schizophrenia. *Annu Rev Clin Psychol*. 2019;15:451–479.
139. Beebe DW, Field J, Milller MM, Miller LE, LeBlond E. Impact of multi-night experimentally induced short sleep on adolescent performance in a simulated classroom. *Sleep*. 2017;40(2):zsw035. https://doi.org/10.1093/sleep/zsw035.
140. Beebe DW, Rose D, Amin R. Attention, learning, and arousal of experimentally sleep-restricted adolescents in a simulated classroom. *J Adolesc Health*. 2010;47(5):523–525.
141. Wahlstrom K. The Prickly politics of school starting times. *Phi Delta Kappan*. 1999;80(5):344–347.
142. Owens J, Drobnich D, Baylor A, Lewin D. School start time change: an in-depth examination of school districts in the United States. *Mind Brain Educ*. 2014;8(4):182–213.
143. Bertsimas D, Delarue A, Martin S. Optimizing schools' start time and bus routes. *Proc Natl Acad Sci U S A*. 2019;116(13):5943–5948.
144. Start School Later. Myths and misconceptions. Available at: https://www.startschoollater.net/myths-and-misconceptions.html. Accessed April 5, 2021.
145. Copenhaver EA, Diamond AB. The value of sleep on athletic performance, injury, and recovery in the young athlete. *Pediatr Ann*. 2017;46(3):e106–e111.
146. Wolfson AR, Harkins E, Johnson M, Marco C. Effects of the Young Adolescent Sleep Smart Program on sleep hygiene practices, sleep health efficacy, and behavioral well-being. *Sleep Health*. 2015;1(3):197–204.
147. Mindell JA, Sedmak R, Boyle JT, Butler R, Williamson AA. Sleep well!: A pilot study of an education campaign to improve sleep of socioeconomically disadvantaged children. *J Clin Sleep Med*. 2016;12(12):1593–1599.
148. Wing YK, Chan NY, Man Yu MW, et al. A school-based sleep education program for adolescents: a cluster randomized trial. *Pediatrics*. 2015;135(3):e635–e643.

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149. Wilson KE, Miller AL, Bonuck K, Lumeng JC, Chervin RD. Evaluation of a sleep education program for low-income preschool children and their families. *Sleep*. 2014;37(6):1117–1125.
150. Bauducco SV, Flink IK, Boersma K, Linton SJ. Preventing sleep deficit in adolescents: Long-term effects of a quasi-experimental school-based intervention study. *J Sleep Res*. 2020;29(1):e12940.
151. Quan S, Ziporyn P. The impact of an online prematriculation sleep course (Sleep 101) on sleep knowledge and behaviors in college freshmen: a pilot study. *Southwest J Pulm Crit Care*. 2017;14(4):159–163.
152. Quan SF, Ziporyn PS, Czeisler CA. Sleep education for college students: the time is now. *J Clin Sleep Med*. 2018;14(7):1269.
153. So RJ, Gibney SF, Czeisler ME, et al. 0977 engagement in collegiate sleep health education: a matter of timing. *Sleep*. 2019;42:A393–A394.
154. Barger LK, O'Brien CS, Rajaratnam SM, et al. Implementing a sleep health education and sleep disorders screening program in fire departments: a comparison of methodology. *J Occup Environ Med*. 2016;58(6):601–609.
155. Arora VM, Georgitis E, Woodruff JN, Humphrey HJ, Meltzer D. Improving sleep hygiene of medical interns: can the sleep, alertness, and fatigue education in residency program help? *Arch Intern Med*. 2007;167(16):1738–1744.
156. Mindell JA, Bartle A, Wahab NA, et al. Sleep education in medical school curriculum: a glimpse across countries. *Sleep Med*. 2011;12(9):928–931.
157. Ye L, Smith A. Developing and testing a sleep education program for college nursing students. *J Nurs Educ*. 2015;54(9):532–535.
158. Agaku IT, Obadan EM, Odukoya OO, Olufajo O. Tobacco-free schools as a core component of youth tobacco prevention programs: a secondary analysis of data from 43 countries. *Eur J Public Health*. 2015;25(2):210–215.
159. Farrelly MC, Niederdeppe J, Yarsevich J. Youth tobacco prevention mass media campaigns: past, present, and future directions. *Tob Control*. 2003;12(suppl 1):i35–i47.
160. Salzberg PM, Moffat JM. Ninety five percent: an evaluation of law, policy, and programs to promote seat belt use in Washington state. *J Safety Res*. 2004;35(2):215–222.
161. Collins TA, Indorf C, Klak T. Creating regional consensus for starting school later: a physician-driven approach in southern Maine. *Sleep Health*. 2017;3(6):479–482.
162. Dunietz GL, Matos-Moreno A, Singer DC, Davis MM, O'Brien LM, Chervin RD. Later school start times: what informs parent support or opposition? *J Clin Sleep Med*. 2017;13(7):889–897.
163. Meltzer LJ, McNally J, Plog AE, Siegfried SA. Engaging the community in the process of changing school start times: experience of the Cherry Creek School District. *Sleep Health*. 2017;3(6):472–478.
164. Ziporyn T, Wake J. Using sleep science to inform policy: the case of school start times. *Sleep Health*. 2020;6(1):2–3.
165. Ziporyn TD, Malow BA, Oakes K, Wahlstrom KL. Self-report surveys of student sleep and well-being: a review of use in the context of school start times. *Sleep Health*. 2017;3(6):498–507.
166. Berger AT, Widome R, Troxel WM. School start time and psychological health in adolescents. *Curr Sleep Med Rep*. 2018;4(2):110–117.
167. Twenge JM, James S, Coyne SM. *Teens Dissatisfied With Virtual School*. The Wheatley Institution; 2021.
168. Gruber R, Saha S, Somerville G, Boursier J, Wise MS. The impact of COVID-19 related school shutdown on sleep in adolescents: a natural experiment. *Sleep Med*. 2020;76:33–35.
169. Lim MTC, Ramamurthy MB, Aishworiya R, et al. School closure during the coronavirus disease 2019 (COVID-19) pandemic—impact on children's sleep. *Sleep Med*. 2021;78:108–114.
170. Meltzer L, Wahlstrom K, Owens J, et al. 675 COVID-19 instruction style (in-person, virtual, hybrid), school start times, and sleep in a large nationwide sample of adolescents. *Sleep*. 2021;44(suppl 2):A264.
171. Lewis LL. How remote school underscored the importance of later school start times. *GreatSchools*. 2021. https://www.greatschools.org/gk/articles/how-remote-school-underscored-the-importance-of-later-school-start-times/.
172. Meltzer LJ, Saletin J, Honaker S, et al. COVID-19 instructional approaches (in-person, online, hybrid), school start times, and sleep in over 5,000 U.S. adolescents. *Sleep*. 2021;44(12):1–10. (In press).
173. Weingart R, Bryan C, Olson D, et al. Adolescent sleep duration and timing during early COVID-19 school closures. *Sleep Health*. 2021;7(6):543–547.
174. Malone SK, Ziporyn T, Buttenheim AM. Applying behavioral insights to delay school start times. *Sleep Health*. 2017;3(6):483–485.
175. Chang C. Motivated processing: how people perceive news covering novel or contradictory health research findings. *Sci Commun*. 2015;37(5):602–634.
176. Han PKJ, Zikmund-Fisher BJ, Duarte CW, et al. Communication of scientific uncertainty about a novel pandemic health threat: ambiguity aversion and its mechanisms. *J Health Commun*. 2018;23(5):435–444.
177. Oreskes N, Conway EM. *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues From Tobacco Smoke to Global Warming*. 1st U.S. ed. New York: Bloomsbury Press; 2010.
178. Peters HP, Brossard D, de Cheveigne S, et al. Science communication. Interactions with the mass media. *Science*. 2008;321(5886):204–205.
179. Peters HP. Gap between science and media revisited: scientists as public communicators. *Proc Natl Acad Sci U S A*. 2013;110(suppl 3):14102–14109.
180. Greifeneder R, Jaffe M, Newman E, Schwarz N. *The Psychology of Fake News: Accepting, Sharing, and Correcting Misinformation*. London and New York: Routledge Taylor & Francis Group; 2021.
181. Smith CN, Seitz HH. Correcting misinformation about neuroscience via social media. *Sci Commun*. 2019;41(6):790–819.
182. Chan M-pS, Jones CR, Hall Jamieson K, Albarracín D. Debunking: a meta-analysis of the psychological efficacy of messages countering misinformation. *Psychol Sci*. 2017;28(11):1531–1546.

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