Adolescent Sleep Delay and School Start Times

A Review of the Literature and Lessons Learned from Other Districts

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June Han, Ph.D.

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Executive Summary

Contrary to popular belief, teenagers cannot just force themselves to go to bed earlier. Based on biological processes, adolescents experience a delay in sleep preference, meaning they have a natural tendency to fall asleep later at night and wake up later in the morning. Older adolescents experience this delay to a greater degree than adolescents who are in the earlier stages of puberty. While adolescents need at least eight to nine hours of sleep per night, studies show that most teens are not getting the sleep that they need, leaving them sleepy and in some cases chronically sleep-deprived.

Inadequate sleep results in daytime sleepiness, which can negatively affect outcomes related to academic achievement, cognitive functioning, physical and mental health, risk-taking behavior, and safety. Inadequate sleep can lead to cognitive, behavioral, and mood impairments and difficulties with paying attention and controlling impulses and emotions, and sleep deprived adolescents are at higher risk for depression, suicide, obesity, and substance abuse, among a host of other problems.

Many researchers argue that early school start times are incompatible with adolescent sleep patterns, and studies show that later school start times result in students getting more sleep, leading to a range of positive outcomes in the areas named above. Studies have shown that when schools delay start times, students generally go to bed at the same time, further supporting the notion of a biologically set bedtime. While school start times for high school students should ideally be 8:30 a.m. or later, even a modest delay in start time has been associated with significant improvements on student outcomes.

Based on the scientific research, many school districts have decided to implement later school start times. Decisions to delay start times can be contentious as major scheduling changes may disrupt families and communities. In making the decision, districts should consider the impact of a start time change on transportation and traffic flow, after school sports and other extracurricular activities, parents' and teachers' work schedules, before and after school childcare, students' after school employment, and effects on younger students, among other factors.

Districts considering a start time change should educate the community about the importance of adequate sleep on adolescent health and development. Districts should also engage and seek input from the community, respond to questions and concerns, obtain feedback from students, teachers, and principals, and provide translation and translated material to non-English speakers. Once a decision to delay start times has been made, families and communities should be given as much time as possible to adjust to the changes. Following up on outcomes after a change in start times is also important.

The leadership of the district superintendent can be a critical component as to whether school districts are successful in changing their start times. Districts that have been the most successful in this area are those in which the superintendent, district staff, and the school board are well-informed on the issues and have reached out and worked with community members and organizations to address challenges, dispel misconceptions, and propose solutions that benefit students.

Strategies that other districts have employed to delay start times include "flipping" high school start times with elementary and/or middle schools, delaying start times at all levels, shifting only high school or high school and middle school start times, and instituting flexible start or dismissal times. Yet others have opted to conduct pilot studies to assess the impact of a start time change before going ahead with a full-scale, district-wide implementation.

Introduction

Teenagers generally go to bed and wake up significantly later than younger children, and data from all over the world indicate that adolescents report going to bed later as they get older (Crowley, Acebo, & Carskadon, 2007; Jenni, Achermann, & Carskadon, 2005). Until fairly recently, this was thought to be a phenomenon based on environmental and psychosocial rather than biological factors (Carskadon, Vieira, & Acebo, 1993).

Some of the environmental and psychosocial factors that have led to later bedtimes among adolescents include less parental influence on bedtimes, more homework, after school sports and other extracurricular activities, and stimulating activities that include watching TV, playing video games, and using the computer (see Crowley et al., 2007, p. 602-603).

Adolescent Development and Circadian Phase

In the early 1990s, research emerged that showed that there may be biological processes behind an adolescent sleep preference delay as the circadian timing system (which basically acts as a "clock" to regulate sleep and behavior) undergoes developmental changes during adolescence (Carskadon et al., 1993). The theory is that a delay of circadian phase during adolescent development contributes to the delay of sleeping times in adolescents, and therefore adolescents experience a biological tendency toward later bedtimes and wake times (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998).

Since the 1990s, Carskadon and colleagues have produced data that show a relationship between adolescent development and circadian phase and provided laboratory evidence to suggest that the circadian timing system changes during puberty, with an increase in pubertal stage associated with a delay in circadian timing (Carskadon, Acebo, Richardson, Tate, & Seifer, 1997; Carskadon et al, 1998; Carskadon, Acebo, & Jenni, 2004).

Two-Process Model of Sleep Regulation

Researchers have incorporated and built on Borbély's (1982) Two-Process Model of Sleep Regulation to explain how developmental changes during adolescence translate to a shift in sleep/wake patterns (Carskadon et al., 2004; Jenni et al., 2005; Taylor et al., 2005).[1]

In a comprehensive review article, Crowley et al. (2007) outline this model, which incorporates circadian (Process C) and sleep/wake homeostatic (Process S) components. The circadian timing system facilitates sleep/wake cycles and behavior, such as feeding and reproduction. These coordinated patterns, or circadian rhythms, are self-sustained and fluctuate within a 24-hour period.

Humans secrete a hormone called melatonin, which rise and fall with a circadian rhythm (levels rise in the evening around bedtime, stay relatively constant during night time, and decline close to the time

[1] Borbély (1982) called the circadian component Process C and the homeostatic sleep/wake component Process S. Sleep occurs when Process S reaches an upper threshold and wake occurs when Process S is below a lower threshold. Process C controls the thresholds by acting almost like a thermostat. According to this model, sleep is initiated at one circadian phase, and wake is initiated at a different circadian phase (as cited in Crowley et al., 2007, p. 605).

that one generally wakes). The daily variation of daylight and darkness provides the primary "organizing stimulus" for the circadian timing system (Crowley et al., 2007, p. 604).

Humans generally respond to light in a predictable manner, where light during the end of day and beginning of night shifts circadian rhythms later (referred to as phase delay), and bright light during the end of night or beginning of day shifts circadian rhythms earlier (referred to as phase advance) (Crowley et al., 2007).

In addition to the circadian system, homeostatic sleep/wake processes, which are controlled by brain mechanisms and are relatively independent of circadian timing, play a role in the regulation of sleep and wake. The way these processes work is that sleep pressure increases the longer one is awake and declines as one sleeps (Crowley et al., 2007).

Homeostatic Sleep Regulation in Adolescents

Researchers have found that certain aspects of the homeostatic system are unchanged from late childhood to young adulthood, whereas other features change in a manner that allows for later bedtimes among older adolescents (Carskadon et al., 2004; Jenni et al., 2005; Taylor, Jenni, Acebo, and Carskadon, 2005).

For instance, the results of one study showed a slower accumulation of sleep pressure in mature adolescents as compared to pre- or early pubertal adolescents under conditions of sleep deprivation, leading the investigators to conclude that developmental changes in homeostatic sleep regulation contribute to adolescent sleep phase delay (Jenni et al. 2005). Taylor et al. (2005), who achieved similar results in their study, conclude that a sleep phase delay driven by changes in circadian and sleep/wake regulation is a "normative developmental process of adolescence" (p. 243).

In sum, sleep/wake timing shifts later during adolescence, and this shift is attributed to environmental, psychosocial, *and* biological factors (Crowley et al., 2007).

Sleep Deprivation among Adolescents

Various studies point to the "epidemic" of sleep deprivation among adolescents (Hagenauer, Perryman, Lee, & Carskadon, 2009; Hansen, Janssen, Schiff, Zee, & Dubocovich, 2005; Roberts, Roberts, & Duong, 2009). One study, which defined sleep deprivation as six hours or less of sleep per night during the past four weeks, found that it is prevalent and chronic among adolescents (Roberts et al., 2009).

It was reported in a 2006 National Sleep Foundation survey that only one in five adolescents gets an optimal nine hours of sleep on school nights, and nearly one-half (45 percent) sleep less than eight hours on school nights. In addition, more than half of the adolescents in the survey said they feel tired or sleepy during the day.

Hagenauer et al. (2009) state that this sleep deprivation is due partly to pubertal changes in the homeostatic and circadian regulation of sleep; evening light exposure and early school start times, they argue, make the problem worse.

As an example of the impact of early school start times, the tenth grade students in Carskadon et al.'s (1998) study, who transitioned from a start time of 8:25 a.m. in ninth grade to a start time of 7:20 a.m. the following year, were described as "pathologically sleepy" (p. 878) and were observed to be carrying a "significant chronic sleep debt" (p. 879).

Layout of the Report

In this report, I first outline the recommendations made by the American Academic of Pediatrics (AAP) in an August 2014 policy statement. I then provide a review of the literature from relevant fields on the effects of sleep duration on academic achievement, daytime functioning, physical and mental health, risk-taking behavior, and motor vehicle crashes among adolescents (focusing specifically on high school students). I also discuss the effects of school start times on student outcomes. The following section presents short case summaries on the experiences of other districts, including those that have successfully delayed start times and those that chose in the end not to change start times. I follow this section with a discussion of the potential implications of moving to a later start time by discussing the challenges and concerns that are commonly identified around this issue and the differential impact that changing school start times may have. It also provides recommendations for school and district administrators. The subsequent section highlights findings from the Children's National Medical Center's (CNMC) Blueprint for Change Team (2014) report, which examines the process by which school districts consider, approve, and implement changes in school start times and serves as a valuable resource for districts that are considering a start time change. The report concludes with a list of the academic references that were cited in this document.

AAP Policy Statement

An AAP (2014) policy statement regarding school start times for adolescents states the following:

> The American Academy of Pediatrics recognizes insufficient sleep in adolescents as an important public health issue that significantly affects the health and safety, as well as the academic success, of our nation's middle and high school students. Although a number of factors, including biological changes in sleep associated with puberty, lifestyle choices, and academic demands, negatively affect middle and high school students' ability to obtain sufficient sleep, the evidence strongly implicates earlier school start times (i.e., before 8:30 AM) as a key modifiable contributor to insufficient sleep, as well as circadian rhythm disruption, in this population. Furthermore, a substantial body of research has now demonstrated that delaying school start times is an effective countermeasure to chronic sleep loss and has a wide range of potential benefits to students with regard to physical and mental health, safety, and academic achievement. The American Academy of Pediatrics strongly supports the efforts of school districts to optimize sleep in students and urges high schools and middle schools to aim for start times that allow students the opportunity to achieve optimal levels of sleep (8.5–9.5 hours) and to improve physical (eg, reduced obesity risk) and mental (eg, lower rates of depression) health, safety (eg, drowsy driving crashes), academic performance, and quality of life (p. 642).

In Table 1 (on p. 643), the impact of chronic sleep loss in adolescents is listed as follows:

On Physical Health and Safety

- Increased obesity risk
- Metabolic dysfunction (hypercholesterolemia, type 2 diabetes mellitus)
- Increased cardiovascular morbidity (hypertension, increased risk of stroke)
- Increased rates of motor vehicle crashes ("drowsy driving")
- Higher rates of caffeine consumption; increased risk of toxicity/overdose
- Nonmedical risk of stimulant medications; diversion
- Lower levels of physical activity

On Mental Health and Behavior

- Increased risk for anxiety, depression, suicidal ideation
- Poor impulse control and self-regulation; increased risk-taking behaviors
- Emotional dysregulation; decreased positive affect
- Impaired interpretation of social/emotional cues in self and others
- Decreased motivation
- Increased vulnerability to stress

On Academics and School Performance

- Cognitive deficits, especially with more complex tasks
- Impairments in executive function (working memory, organization, time management, sustained effort)
- Impairments in attention and memory
- Deficits in abstract thinking, verbal creativity

- Decreased performance efficiency and output
- Lower academic achievement
- Poor school attendance
- Increased dropout rate

Sleep and Student Outcomes: A Review of the Literature

Many scientific studies point to the negative effects of inadequate sleep and sleep disruption on a multitude of student outcomes, ranging from lower academic performance to impaired daytime functioning and higher variability in mood and behavior. Among adolescents, sleep problems are strongly associated with depression and suicide, and numerous studies establish an association between inadequate sleep and obesity. Sleep problems can also lead to high-risk behaviors, such as substance abuse, and sleepiness and fatigue have been found to contribute to an increase in motor vehicle accidents among teen drivers.

Carskadon et al. (2004) argue that many adolescents are sleep deprived from having too little sleep at the wrong circadian phase, leading to increased risks for excessive sleepiness, difficulty with mood regulation, impaired academic performance, learning difficulties, school tardiness and absenteeism, and accidents and injuries.

A closely associated factor related to sleep duration among teens is school start times. Crowley et al. (2007) note that "[e]arly rising for school is unwelcome and forced for most adolescents" (p. 603). They also observe that there is a difference between weekend and school night bedtimes among adolescents of about one to two hours—a difference that is usually greater among older rather than younger adolescents (Crowley et al., 2007).

Similarly, Carsksadon et al. (1998) point out that teenagers "confront a powerful social demand in opposition to the phase-delay tendency: school starting time" (p. 872). While it is a common practice in school districts to begin school earlier for adolescents than for younger children, they point out that "[t]his advance of the school day is in direct conflict with pubertal/adolescent phase delay" (Carskadon et al., 1998, p. 872).

Various studies have examined the impact of sleep duration and school start times on student outcomes related to academic achievement, mental and physical health, and safety. While it is beyond the scope of this review to examine all of the growing literature in this area, an attempt was made to cite scholarly publications that have made a substantive contribution to the debates and discussions around this important issue.

Effects on Academic Achievement

A number of studies have found that adequate sleep and later school start times have a significant positive effect on student achievement (Carrell, Maghakian, & West, 2011; Jacob & Rockoff, 2011)

Carrell et al. (2011) refer to the growing body of research that finds that many adolescents are sleep-deprived because of early school start times and changing sleep patterns during the teen years. Their study attempts to uncover the causal effect of school start time on academic achievement by using two policy changes in the daily schedule at the U.S. Air Force Academy along with the randomized placement of freshman students to courses and instructors. Results from their study show that starting the school day 50 minutes later has a significant positive effect on student achievement, roughly equivalent to raising teacher quality by one standard deviation (Carrell et al., 2011). While their study is unique in that

they are trying to establish a causal relationship rather than just an association between school start time and academic achievement, their study focuses on college freshmen at a military academy rather than high school students.

Jacob and Rockoff (2011) point to changing school start times as an organizational reform that evidence suggests has the potential to increase K-12 student performance at relatively modest costs. They note that early school start times substantially reduce the academic performance of all students, but particularly among disadvantaged students. Jacob and Rockoff (2011) propose that districts with tiered busing systems in which middle or high schools start early could switch to having elementary schools start first or eliminate the tiered system and have all schools start at the same time. They cite another study which estimates that it would cost roughly $150 per student (or $1,950 per student over K-12) to allow all students to shift their school start time to 9:15 a.m. (Edwards, 2012, as cited in Jacob & Rockoff, 2011). On the other hand, based on Carrell et al.'s (2011) assessment that moving start times one hour later for students in grades 6-12 would increase student achievement by roughly 0.175 standard deviation on average, Jacob and Rockoff (2011) estimate that moving start times one hour later would result in roughly $17,500 in increased future earnings per student (in today's present value). Accordingly, they conclude that while transportation systems within school districts may need to be reorganized at potentially considerable costs, "even then the benefits to students more than justify the organizational costs" (Jacob & Rockoff, 2011, p. 26).

A meta-analysis by Dewald, Meijer, Oort, Kerkhof, and Bogels (2010) shows that sleep duration, sleep quality, and sleepiness are significantly but modestly related to school performance, as measured by questionnaires, standardized tests, or grade point average (GPA), with sleepiness showing the strongest association with school performance followed by sleep quality and sleep duration. However, because there are causal links between sleepiness and sleep duration and quality (Beebe, 2011; Fallone, Owens, & Deane, 2002; O'Brien, 2009), it may be that the variables are all closely interrelated—with sleep quality and sleep duration serving as important mediating factors in determining sleepiness.

A study by Pagel, Forister, and Kwiatkowki (2007) provides evidence that sleep disturbances occur at high rates among adolescents and significantly affect academic performance, as measured by students' GPA. In the study, variables related to daytime sleepiness were significantly correlated with poor school performance. When Pagel et al. (2007) controlled for students' socioeconomic status (SES) as measured by students' household income, some of the sleep variables in their study were no longer significantly associated with school performance. However, students who reported that they always experience daytime sleepiness continued to show significantly lower GPAs. This study points to SES as an important mediating or moderating factor on sleep and academic performance, and may partly explain why later school start times could potentially have a greater positive effect on disadvantaged students.

A number of review articles have examined the relationship between sleep and academic achievement among adolescents. In a review on this topic, Wolfson and Carskadon (2003) point to findings that strongly indicate that self-reported shortened sleep time, erratic sleep/wake schedules, late bed and rise times, and poor sleep quality are negatively associated with academic performance for adolescents from middle school through the college years.

Curcio, Ferarra, and De Gennaro (2006) report findings that suggest that students are chronically sleep deprived and cite studies that show that sleep quality and quantity are closely related to student learning capacity and academic performance. Studies in which sleep was restricted showed a decline in

neurocognitive and academic performance, whereas studies in which sleep was optimized showed an improvement in these areas.

One study which finds no effect of school start times on academic achievement is by Hinrichs (2011). The research setting is the Twin Cities metropolitan area, where Minneapolis and several suburban districts have implemented later school start times, but St. Paul and other suburban districts have maintained early schedules. The study employs individual-level ACT data for students in public high schools in the region who took the ACT between 1993 and 2002 to examine the effects of school start times along with school-level data on schedules and test scores on statewide standardized tests from Kansas and Virginia to estimate the effects of school start times on achievement for a broader sample. Findings from the study do not suggest an effect of school start times on achievement as defined by ACT test scores (Hinrichs, 2011). Criticisms of this study relate to the fact that the ACT is but one aspect of student achievement and the fact that the ACT is given in the morning when adolescents are not at their peak time of cognitive functioning.

Effects on Daytime Functioning

One way in which inadequate sleep may be linked to poor academic performance is because of the negative effects of sleepiness and other sleep-related problems on various aspects of daytime functioning (Beebe, 2011).

Beebe (2011) summarizes the results of various studies and finds that inadequate sleep quality and quantity are causally linked to sleepiness, inattention, and other cognitive and behavioral deficits that impact daytime functioning. The review concludes by stating that inadequate sleep can be viewed as a "noxious exposure that can, over time, fundamentally alter a child or adolescent's development, resulting in poorer long-term outcomes" (Beebe, 2011, p. 649).

Dahl (1996) cites a wide range of clinical and observational data that suggest that inadequate sleep results in tiredness, irritability and frustration, and difficulties with paying attention and controlling impulses and emotions—symptoms that may in some cases resemble attention deficit hyperactivity disorder (ADHD)—among children and adolescents. According to Dahl (1996), the strongest effect of sleep deprivation is in the "weakening or diminution of goal-directed behaviors" (p. 48). The article highlights the role of the prefrontal cortex (PFC) of the human brain in organizing cognitive, emotional, and attentional processes and discusses the PFC and its sensitivity to the effects of sleep deprivation.

Dahl and Lewin (2002) focus on sleep regulation in relation to healthy adolescent development and argue that sleep deprivation has its greatest negative effects on the control of behavior, emotion, and attention. They add that the most obvious direct health consequences of insufficient sleep are high-risk behaviors associated with substance abuse and automobile accidents (Dahl & Lewin, 2002).

In a comprehensive review, Fallone et al. (2002) point to empirical evidence that clearly indicates that children and adolescents experience significant daytime sleepiness as a result of inadequate or disturbed sleep, which can lead to impairments in behavior and mood and a decline in cognitive flexibility and abstract reasoning abilities (as cited in Wolfson & Carskadon, 2003, p. 502-503).

O' Brien (2009) points out that sleep problems in children and adolescents are common, and that sleep disruption is associated with a wide range of behavioral, cognitive, and mood impairments, including

hyperactivity, lower grades in school, and depression. While sleepiness, sleep duration, and sleep quality are sometimes seen as separate factors, they are related in that insufficient or fragmented sleep can cause sleepiness (O'Brien, 2009).

School Start Times and Daytime Functioning

A number of studies specifically examine the impact of school start times on various aspects of daytime functioning (Hansen et al., 2005; Owens, Bellon, & Moss, 2010; Wolfson & Carskadon, 1998).

Owens et al. (2010) assess the impact of a 30-minute delay in school start time on adolescents' sleep, mood, and behavior. Students in grades 9 through 12 (n=201) at an independent high school in Rhode Island participated in the study by competing the online retrospective Sleep Habits Survey before and after a change in school start time from 8:00 to 8:30 a.m. After the start time delay, sleep on school nights increased by an average of 45 minutes, and students went to bed 18 minutes earlier (in contrast to other studies where bedtimes stayed at about the same time). The percentage of students getting less than seven hours of sleep decreased by 79 percent, and those reporting at least eight hours of sleep increased by almost 40 percent. Students reported significantly more satisfaction with sleep and experienced improved motivation. Daytime sleepiness, fatigue, and depressed mood were all reduced. Most health-related variables, such as Health Center visits for fatigue-related complaints, improved, as did class attendance. The study concludes that a modest delay in school start time was associated with significant improvements in measures of adolescent alertness, mood, and health. The results of this study support the benefits of adjusting school schedules to adolescents' sleep needs, circadian rhythm, and developmental stage.

In a widely cited study of 3,120 high school students at four public high schools from three Rhode Island school districts, Wolfson and Carskadon (1998) examine the relationship between adolescents' sleep/wake habits, demographic characteristics of the students (age, sex, etc.), and daytime functioning (mood, school performance, and behavior). They found that self-reported sleep times (on both school and weekend nights) decreased by 40 to 50 minutes between the ages of 13 to 19. Whereas rise times were consistent across ages, students were going to bed at increasingly later times. Students who were getting Cs, Ds, and Fs in their classes reported that they were getting about 25 minutes less sleep and were going to bed about 40 minutes later than students who reported getting As and Bs in their classes. Students with worse grades also reported greater weekend sleep delays than those with better grades. Additionally, students in the short school-night total sleep group (< 6 hr 45 min) and/or large weekend bedtime delay group (> 120 min) reported increased daytime sleepiness, depressive mood, and sleep/wake behavior problems as compared to those sleeping more than eight hours with less than a 60 minute weekend delay. Wolfson and Carskadon (1998) conclude that most of the adolescents in their study were not getting enough sleep, and their sleep loss was interfering with daytime functioning.

In their study of 60 incoming high school seniors, Hansen et al. (2005) explore the impact of starting school on adolescent sleep. Participants kept sleep/wake diaries beginning in August and continuing through two weeks after the start of school in September. They also kept track of their sleep/wake patterns in November and February of the same school year. The adolescents in the study lost as much as 120 minutes of sleep per night during the week after the start of school, and weekend sleep time was also about 30 minutes longer than it was before the start of school in August. No significant differences between weekday sleep in the summer and weekend sleep during the school year were found. Consistent with a delay in circadian sleep phase, students performed better on tests measuring

reasoning, vigilance, and reaction times in the afternoon than in the morning, and students in early morning classes reported being weary and less alert and having to exert greater effort to complete tasks. The study concludes that early high school start times contribute to sleep deprivation among adolescents, and that both short- and long-term strategies will be necessary to address the "epidemic of sleep deprivation among adolescents" (Hansen et al., 2005, p. 1555).

In light of such findings, Kelley, Lockley, Foster, and Kelly (2014) argue that changing school start times can improve academic outcomes and reduce health risks and state that "[s]ynchronizing education start times to adolescent biology is the obvious way to address the problem of chronic sleep deprivation currently experienced by adolescents on school days" (p. 8).

While the pendulum is swinging toward the belief that adolescents are chronically sleep deprived, Matricciani, Olds, Blunden, Rigney, and Williams (2012) offer a different viewpoint by looking at sleep recommendations from a historical perspective. They identified 32 sets of sleep recommendations from 1897 to 2009 and found that recommended sleep was consistently about 37 minutes greater than actual sleep, and that both have declined over time. They conclude by stating that "[n]o matter how much sleep children are getting, it has always been assumed that they need more" (Matricciani et al., 2012, p. 548).

Effects on Physical Health

Sleep Duration and Obesity

There is a growing body of research on the relationship between sleep duration and obesity, and researchers are starting to examine the effects of inadequate sleep on obesity in children and adolescents. While studies show a clear association between sleep duration and obesity among children, the evidence for adolescents is mixed, though there are more studies that find a relationship between sleep duration and obesity among adolescents than those that do not.

In a meta-analysis of short sleep duration and obesity in children and adults, Cappuccio, Taggart, Kandala, Currie, Peile, Stranges, and Miller (2008) identify 696 studies and narrow the pool down to 45 for a total of 36 population samples and over 630,000 participants. They point out that cross-sectional studies from around the world show a consistent increased risk of obesity among short sleepers in children and adults; they note, however, that it is difficult to establish a causal relationship between sleep duration and obesity (Cappuccio et al., 2008).

A meta-analysis by Chen, Beydoun, and Wang (2008) shows a clear association between short sleep duration and increased risk of childhood obesity based on the results of previous studies on diverse populations. In general, studies of children aged nine and younger found an inverse association between sleep duration and overweight/obesity, with shorter sleep associated with overweight/obesity. Findings from studies on adolescents, on the other hand, were somewhat inconsistent. Although most studies on adolescents showed a significant association between short sleep duration and obesity, others reported no association, especially among girls (Chen et al., 2008).

In a review on the role of sleep and sleep loss on hormonal release and metabolism, Leproult and Van Cauter (2010) cite evidence that indicates that chronic sleep loss may increase the risk of obesity and weight gain by contributing to metabolic and endocrine-level changes, including decreased glucose

tolerance, decreased insulin sensitivity, increased levels of cortisol and ghrelin, decreased levels of leptin, and increased hunger and appetite. Leproult and Van Cauter (2010) point to the possible role of inadequate sleep in the current epidemic of obesity and conclude that "[a]voiding sleep deprivation may help to prevent the development of obesity, particularly in children" (p. 11).

According to Marshall, Glozier, and Grunstein (2008), studies that point to a relationship between short sleep duration and obesity "generate wide media attention because of the public's health concerns surrounding increasing obesity and the temporal association with the other modern 'epidemic' of sleep loss" (p. 289). They review the literature on the relationship between sleep duration and obesity and conclude that the research on adults is mixed. On the other hand, they observe a clear pattern where short sleep duration was associated with obesity in pediatric populations (ages 3 to 19). Five out of the six studies cited by Marshall et al. (2008) that included teenagers showed an association between short sleep duration and obesity, with only one study showing no association.

Sleep and BMI

In a widely cited study on the association between sleep duration and body mass index (BMI), Taheri, Lin, Austin, Young, and Mignot (2004) found that short sleep duration is associated with reduced leptin, elevated ghrelin, and increased BMI. Study participants were 1,024 volunteers from a population-based longitudinal study of sleep disorders in Wisconsin. Participants with short sleep had reduced leptin and elevated ghrelin, and differences in leptin and ghrelin are likely to increase appetite, possibly explaining the increased BMI that is associated with short sleep duration (Taheri et al., 2004). Taheri (2006) recommends more sleep to prevent obesity and advocates for an "obesity prevention approach in children and adolescents that promotes a healthy diet, physical activity and adequate sleep" (p. 883).

In a study examining the association between short sleep duration and obesity among a nationally representative sample of South Korean adolescents (n=73,836, subjects were 12-18 years-old), Park (2011) found that sleep duration is inversely associated with BMI and risks for overweight and obesity. The percentage of overweight or obese subjects was the greatest among respondents reporting less than five hours of sleep (14.1 percent) and lowest among respondents reporting eight hours or more of sleep (11.9 percent). Additionally, with a one-hour decrease in sleep duration, the likelihood of being overweight or obesity increased by 6.5 percent. The study showed that shorter sleep duration was significantly associated with greater risks for being overweight or obesity, even after controlling for obesity-related factors such as gender, SES, and lifestyle. Park (2011) notes that while an association is clear, the underlying mechanisms behind this association remain unclear.

Snell, Adam, and Duncan (2007) use longitudinal data from a nationally representative sample of 2,281 children aged 3-12 years at baseline to examine the associations between sleep and BMI. Controlling for baseline BMI, they found that children who slept less, went to bed later, or got up earlier at the time of the first assessment had higher BMIs five years later and were more likely to be overweight. One interesting finding in the study was that child age moderated the relationship between bedtime and BMI. Because BMI increases dramatically during puberty, and because sleep amounts can influence the endocrine hormones that affect the timing and onset of puberty, "puberty could act as a major mediator or moderator of causal linkages between sleep and weight" (Snell et al., 2007, p. 321).

The fact that the onset of puberty relates more to the older children in the study could have implications on findings that sleep has more of an effect on the BMI of younger children than older children. On this,

Snell et al. (2007) write: "That is, perhaps we find that sleep matters more for younger children's BMI because our inability to account for pubertal status weakens the association between BMI and sleep for older children" (p. 321). They go on to directly address the debate over school start times for adolescents by stating that

> earlier bedtime may be more important for younger children's and later waketime more important for older children's subsequent BMI and overweight status. If so, parents should be encouraged to put their younger children to be early enough so that they can sleep at least 10 or 11 hr a night. For older children, however, only later waketimes were associated with lower BMI and lower rates of overweight. This result supports findings from the growing sleep literature encouraging later school start times, particularly for adolescents (Snell et al., 2007, p. 322).

Thus, to maximize positive outcomes, not just with weight and BMI but also in other areas, the key may to be allow adolescent students to wake up later, whereas for younger children it is more important to get them to go to sleep earlier.

No Association between Sleep and Obesity

On the other hand, a number of studies find no association between sleep duration and obesity among adolescents (Calamaro, Park, Mason, Marcus, Weaver, Pack, & Ratcliffe, 2010; Lytle, Murray, Laska, Pasch, Anderson, & Farbakhsh, 2013).

Using data from the National Longitudinal Study of Adolescent Health (survey of 90,000 youths, ages 12-18), Calamaro et al. (2010) found that shortened sleep duration does not predict obesity in adolescents. Factors such as watching TV for more than two hours per day and depression were significantly associated with obesity, whereas shortened sleep duration was not. However, the study notes that the nature of the relationship between the timing and amount of television watching and shortened sleep is unclear, where television viewing may result in later sleep onset. In that case, "late night television watching may be a pathway by which adolescents have shorted sleep duration" (Calamaro et al., 2010).

Lytle et al. (2013), in their study examining how change in sleep may impact change in weight over time, did not find that a decline in sleep duration during adolescence increases the risk of obesity. They note that the evidence from empirical research, especially longitudinal studies, is "showing that the association between sleep and obesity risk is moderated by age, with lack of sleep in young children being an important risk factor for subsequent obesity" (Lytle et al., 2013). Despite their results, they do note, however, that the overall evidence for the association between sleep duration and BMI in adolescents is mixed.

Effects on Mental Health

Inadequate and disrupted sleep has negative impacts on multiple areas related to mental health. For instance, Winsler, Deutsch, Vorona, Payne, and Szklo-Coxe Winsler (2014) found that just one hour less of weekday sleep was associated with significantly greater odds of feeling hopeless, seriously considering suicide, suicide attempts, and substance use among the adolescents surveyed in their study

(n=27,939, grades 8, 10, and 12), leading the investigators to conclude that insufficient sleep is a risk factor for depression, suicidality, and substance use.

Sleep Problems and Depression

More studies are beginning to demonstrate a relationship between sleep problems and depression (Moore, Kirchner, Drotar, Rosen, Ancoli-Israel, & Redline, 2009; Roberts & Duong, 2013). I have highlighted the findings of two studies below, but many of the articles reviewed in this report found a significant relationship between inadequate and disrupted sleep and depression.

In one study, sleepiness was associated with higher scores on measure of anxiety, depression, and a more negative self-perception of health among adolescents (Moore et al., 2009). This was a cross-sectional analysis of data from study on sleep and health (n=247, mean age of 13.7 years).

In another study examining the relationship between insomnia and major depression among adolescents (3,134 youths aged 11-17 at baseline), Roberts and Duong (2013) found that that the two are related, and the association between insomnia and depression was stronger and more consistent for major depression than for symptoms of depression.

Sleep Problems and Suicide

Suicide risk begins to increase during adolescence (Liu, 2004), and a number of studies have explored the link between sleep and suicide and suicidal behavior among adolescents (Liu, 2004; Fitzgerald, Messias, & Buysse, 2011; Goldstein, Bridge, & Bent 2008).

Liu (2004) studied the association between sleep and adolescent suicidal behavior among adolescents in China (n=1,362, mean age 14.6 years). Results from self-reported data showed that sleeping less than eight hours at night was significantly associated with an increased risk of suicide attempts after adjusting for age, sex, father's occupation, and depressive symptoms. These findings demonstrate the association between short sleep duration and suicidal behavior and highlight the potential role of sleep intervention in the prevention of adolescent suicide (Liu, 2004)

Fitzgerald et al. (2011) found that teens (in grades 9-12) who reported sleeping less than five hours or more than ten hours per night had a significantly higher risk for suicidality that those with a total sleep time (TST) of eight hours. Their study concludes that short *and* long TSTs are risk factors for suicidality among teens, with extreme TSTs indicating an even higher risk. Accordingly, the study recommends self-reports on sleep duration as a potentially useful screening tool for assessing suicide risk (Fitzerald et al., 2011).

Goldstein et al. (2008) examined sleep difficulties preceding death in a sample of adolescent “suicide completers” as compared with a matched sample of community control adolescents and found that the suicide completers had higher rates of overall sleep disturbance, insomnia, and hypersomnia. Their findings point to a significant relationship between sleep problems and completed suicide in adolescents, leading Goldstein et al. (2008) to conclude that “sleep difficulties should therefore be carefully considered in prevention and intervention efforts for adolescents at risk for suicide” (p. 84).

Effects on Risk-Taking Behavior

The most widely cited study on the relationship between adolescent sleep/wake patterns and risk taking behavior is by O'Brien and Mindell (2005), who define risk-taking as "those behaviors that increase the risk of morbidity and/or mortality" (p. 115). Their study required participants to complete the Sleep Habits Survey and the Youth Risk Behavior Survey (n=388, subjects were ages 14-19 and in grades 9-12), Students who obtained the least amount of sleep on school nights reported greater alcohol usage than those who obtained the most sleep on school nights, and students with the biggest difference between their school-night and weekend-night bedtimes reported higher levels of risk-taking behavior. While a link has been established between sleep patterns and risk-taking behavior along with other negative outcomes, O'Brien and Mindell (2005) note that "these relationships are not clear" (p 132).

While the mechanisms behind sleep patterns and adolescent risk-taking are unknown, Wong, Brower, Nigg, and Zucker (2010) make the connection between overtiredness and poor response inhibition. In their study, lower levels of response inhibition among adolescents predicted the number of illegal drugs used, leading Wong et al. (2010) to conclude that the "mediating effect of response inhibition is significant, indicating that overtiredness had an indirect effect on the outcomes via poor response inhibition" (p. 1042). Thus, poor response inhibition brought on by inadequate sleep may be a mediating factor behind the risk-taking behaviors of adolescents with sleep problems.

Sleep and Substance Use

Pasch and colleagues have further explored the relationship between sleep and substance use among adolescents (Pasch, Laska, Lytle, & Moe, 2010; Pasch, Latimer, Cance, Moe, & Lytle, 2012).

Pasch et al. (2010) examine how weekday and weekend sleep patterns are related to adolescent substance use, depressive symptoms, and school truancy through the use of self-report surveys (n=242, mean age 16.4 years). The results of their study suggest that youth who sleep less on weekdays are more likely to experience depressive symptoms and report past month alcohol use and drunkenness. Additionally, youth who go to bed later and wake up later on weekends appear to be more likely to engage in substance use and school truancy. On the other hand, they found that the total amount of sleep on weekends was not associated with risk-taking behaviors among adolescents (Pasch et al., 2010).

Pasch et al. (2012) investigate how sleep and substance use may be related among adolescents by exploring the bi-directional relationships over time between sleep duration, sleep patterns, and substance use among youth. Self-reported substance use behaviors included past month alcohol, cigarette, and marijuana use, and sleep measures included sleep duration on weekends and weekdays, total sleep, and weekend oversleep and sleep delay (n=704, mean age of 14.7 at baseline). After controlling for factors such as pubertal status, BMI, and depressive symptoms, they found bi-directional relationships between cigarette use and weekend sleep and marijuana use and total sleep, leading Pasch et al. (2012) to conclude that sleep patterns and duration are intertwined with substance use among youth.

Effects on Motor Vehicles Crashes

A number of studies show that earlier school start times may contribute to a higher teen crash rate among adolescents, and that later school start times may decrease adolescents' risk of motor vehicle crashes (Danner & Phillips, 2008; Vorona, Szklo-Coxe, Dubik, Zhao, & Ware, 2011).

Danner and Phillips (2008) assess the effects of delayed high school start times on sleep and motor vehicle crashes by examining the sleep habits and crash rates of adolescents from a large, county-wide school district. They administered questionnaires before and after a one-hour delay in school start times and found that average hours of nightly sleep increased and catch-up sleep on weekends decreased. In addition, average crash rates for teen drivers in the study two years after the change in school start time dropped 16.5 percent, whereas teen crash rates for the rest of the state increased 7.8 percent over the same time period. The study concludes by stating that later school start times may serve the dual purpose of increasing the sleep duration of adolescents and decreasing their risk of motor vehicle crashes (Danner & Phillips, 2008).

Vorona et al. (2011) use data from the Virginia Department of Motor Vehicles on weekday crashes and crash times in Virginia Beach (VB) and Chesapeake for drivers aged 16-18 from 2007 to 2008. VB and Chesapeake are adjacent, demographically similar cities, and VB high schools start 75-80 minutes earlier than the high schools in Chesapeake. The study finds that crash peaks in the morning among teen drivers occurred one hour earlier in VB than Chesapeake, which was consistent with school commute times, and that congestion data for VB and Chesapeake did not explain the different crash rates. Based on their results, the investigators conclude that early high school start times may lead to an increase in crash rates among teen drivers who are not getting enough sleep (Vorona et al., 2011).

Longitudinal Studies on School Start Times

A number of researchers have called for more longitudinal studies on the effects of sleep and sleep duration (Dewald et al., 2010; Jenni et al, 2005; Shochat, Cohen-Zion, & Tzischinsky, 2014), as cross-sectional studies only provide data (for a population) at a specific point in time. Wahlstrom has done more longitudinal research on the effects of school start times on student outcomes than any other researcher (Walstrom, 2002; Wahlstrom, Dretzke, Gordon, Peterson, Edwards, & Gdula, 2014).

Wahlstrom (2002) presents findings from a four-year study in a large, urban school district that changed high school start times from 7:15 to 8:40 a.m. The study found significant benefits from the delayed school start time, such as improved attendance and enrollment rates, less sleeping in class, and less student-reported depression. In addition, the study showed that bed times did not change with the later morning start time (students continued to go to bed at around 11:15 p.m. on school nights), and students slept about an hour more each night than students whose schools started at 7:30 a.m. This finding persisted four years into the study, which was contrary to the fears and expectations by some that a later school start time would simply mean that students would go to bed later on school nights (Wahlstrom, 2002).

In a more recent study, Wahlstrom et al. (2014) examined the impact of later school start times on the health and academic performance of high school students at multiple sites. While most studies on this topic focus on single districts at a specific point in time, Wahlstrom et al.'s (2014) study is unique in that it examines several school districts in multiple locations across the U.S. over time. In addition, while

different studies tend to use different metrics to measure results and assess changes, this study uses identical metrics to compare results across districts and over time.

The results of their three-year study, conducted with over 9,000 students in eight public high schools in three states, revealed that high schools that start at 8:30 a.m. or later allow for more than 60 percent of their students to obtain at least eight hours of sleep on school nights (Wahlstrom et al., 2014). Teens getting less than eight hours of sleep reported significantly higher depression symptoms, greater use of caffeine, and are at greater risk of making poor choices related to substance use. On the other hand, teens who reported getting eight or more hours of sleep per night were more likely to say they were in good overall health and were less likely to report being depressed or using caffeine or other substances, such as alcohol and tobacco.

Academic outcomes, including grades earned in math, English, science and social studies and scores on state and national achievement tests, showed significant improvement with school start times of 8:30 or later (Wahlstrom et al., 2014). In addition, attendance rates improved and tardiness rates declined with the later start times. Additionally, there was a significant overall reduction in local car crashes among teens with school start times after 8:30 a.m. In one particular high school, the number of car crashes for teen drivers aged 16 to 18 was reduced by 70 percent after it changed its start time from 7:35 a.m. to 8:55 a.m.

Wahlstrom et. al (2014) conclude that there are empirically-based positive outcomes for adolescents when high school start times are shifted later, with a starting time of 8:30 a.m. or later "clearly showing the most positive results" (p. 52).

Concluding Thoughts

It is important to note that there are some limitations with the scientific literature in this area as many studies rely on self-reports, which are not always reliable, and participants are asked to report information retrospectively, referring to things that happened in the past. As previously mentioned, most of the research is cross-sectional rather than longitudinal, meaning that it looks at a population at a specific point in time rather than assessing changes over time. Also, different variables, indicators, and measures are used in different studies, making it difficult to compare the results across studies. In addition, there is a dearth of laboratory-based, experimental research on the effects of sleep duration on various outcomes. However, as Beebe (2011) points out, it is "neither feasible nor ethical to experimentally expose children to prolonged sleep restriction."

Despite the limitations of the research on sleep duration and academic and health-related outcomes among adolescents, there is overall acceptance among researchers that teens experience a sleep delay in adolescence along with general agreement that teens can benefit in a multitude of ways from getting the sleep they need.

Finally, while this review focuses on sleep/wake patterns and school start times for high school students, it is important to remember that any changes to high school start times may potentially impact start times for elementary and middle school students. Though the research shows that younger adolescents do not experience as much of a sleep delay as older adolescents, there is research that suggests that middle school students may also benefit from later school start times (Edwards, 2012; Lufi, Tzischinsky, & Hadar, 2011).

On the other hand, there is very little research on the impact of school start times on elementary students, though the research is clear that getting enough sleep is vital to the healthy development of younger children. Getting adequate sleep helps children regulate their emotions and be more alert (Gruber, Cassoff, Frenette, Wiebe, & Carrier, 2012) and lowers their risk of obesity and substance use later in life (Wong, Brower, Fitzgerald, & Zucker, 2004), among many other benefits. For younger students, however, the key may be to get them to go to sleep earlier rather than allowing them to wake up later, as is the case with high school age students.

Case Summaries of Other Districts

Below are examples of school districts that were successful in implementing a change in school start times (the case summaries are listed in reverse chronological order, with school districts that made the decision to delay start times more recently listed first):

Fairfax County Public Schools, Virginia

In 2014, the Fairfax County Public Schools (FCPS), which is the eleventh largest school district in the country, decided to implement later start times for its high schools after studying the issue for more than a decade. Citing clear health benefits for adolescents, the Fairfax County School Board approved a recommendation to start high schools between 8:00 to 8:10 a.m. instead of 7:20 a.m. The change will begin in the 2015-16 school year. Middle school students will start at 7:30 a.m., and elementary school start times will remain unchanged between 8:00 to 9:20 a.m. The estimated cost to implement the change in school start times is $5.4 million, and is mainly related to an increase in transportation costs. The district worked with the Children's National Medical Center (CNMC) and a stakeholder committee to develop various options to start high schools in Fairfax County after 8:00 a.m. The options were presented to the community (the district held eight community meetings and gathered more than 2,000 online comments), and based on the feedback that was received, CNMC made a final recommendation to the School Board. The School Board voted in October 2014 to change high school start times. FCPS is socioeconomically and ethnically diverse, and the district is notable in its attempts to provide translation and translated materials for non-English speakers. The FCPS website notes that while middle school times are not yet optimal, the "Superintendent will continue to work on moving them closer to 8 a.m. in the future" (adapted from the FCPS website at http://www.fcps.edu/news/starttimes.shtml).

Albany Unified School District, California

Albany Unified School District is a small district in California with two high schools (one of which serves at-risk youth), one middle school, and three elementary schools. In 2013, the principal from Albany High School proposed moving the school start time of 7:40 a.m. to 8:30 a.m., based on the growing research on the impact of sleep on student outcomes and on feedback from meetings with the community. A task force that included parents, teachers, counselors, school administrators, and students was formed to study the issue and develop a set of recommendations. Based on the recommendations, a small committee, consisting of parents, students, and staff at the high school, agreed to move the start time to 8:00 a.m. as a one-year pilot, during which the district could obtain feedback from the community to assess the impact of the change. The high school proactively sought input from the community by setting up committees and holding a town hall forum (adapted from CNMC's Blueprint for Change Team's 2014 report).

Pulaski County Special School District, Arkansas

In 2012, the Pulaski Special School District (with a student population of 17,500) flipped the start times for its six middle and six high schools with the start time of its 24 elementary schools. Middle school start times moved 50 minutes later from 7:30 a.m. to 8:20 a.m., and high school start times moved later

by 65 minutes from 7:30 a.m. to 8:35 a.m. The start time for elementary schools was 7:20 a.m. The district decided to make these changes based on their interest in reducing transportation costs and improving the health and safety of their students by promoting adequate sleep. To apply the changes, the district went from a single-tier to a two-tier bus schedule. The start time change was initiated by the new district superintendent, who was intent on cutting costs. The district announced the new start times in January and implemented them several months later in September to allow parents and families to have enough time to adjust to the schedule changes. A toll free phone number was set up to field questions and respond to comments from the community (adapted from CNMC's Blueprint for Change Team's 2014 report).

West Hartford Public Schools, Connecticut

West Hartford Public Schools is a district with a student population of 10,222. It has two high schools, three middle schools, and ten elementary schools. In the fall of 2006, the West Hartford Board of Education voted to adopt a flexible start time schedule for juniors and seniors at its two high schools beginning in the fall of the following year. With the flexible start time, students had the option of starting school at 8:15 a.m. (at the start of second period) instead of 7:30 a.m. First period became a study hall, and dismissal remained at 2:15 p.m. for all students, regardless of whether or not they chose the second period start. The district developed this strategy in response to strong community resistance against a uniform delay of high school start times. While the Board of Education acknowledged that this option was a less-than-ideal compromise, it based its decision on the fact that at least some students would be able to take advantage of the delayed time start to obtain sufficient sleep. According to administrators in the district, the later start times had a positive impact on academic performance, student stress levels, and students' emotional health (adapted from CNMC's Blueprint for Change Team's 2014 report).

Bonneville School District, Idaho

The Bonneville School District implemented a new school start time at its two high schools by moving from a 7:45 a.m. start time to 8:50 a.m. in the 1999-2000 school. The district has a student population of 11,200, with two high schools, three middle schools, and 14 elementary schools. A year after implementing the change, the district found that absences dropped by 15 percent, and tardiness decreased by 22 percent. Students also reported getting about 44 minutes more sleep on average after the change in start time and feeling more alert at school. The district followed up with teachers, students, and the local community by reporting the positive impact of the start time change (adapted from CNMC's Blueprint for Change Team's 2014 report).

The following are examples of school districts that decided not to implement a change in start times:

Amherst Regional Public Schools, Massachusetts

In the spring of 2012, Amherst Regional Public Schools issued a report, issued by the Later Start Times Task Force, outlining the reasons why the district should push back high school start times. The report listed five possible options: (1) No change; (2) Switch start times for high school and elementary schools;

(3) Shift all schools 30 minutes later; (4) Put the middle school on the elementary school schedule; and (5) Put all of K-12 on the elementary school schedule. In October 2012, the district presented a report that narrowed the options down to three start time scenarios. However, when the start time change was put to a vote later that month, the proposal for a later high school start time was voted down due to concerns over the financial costs and the potential impact to after school sports and family schedules (adapted from a 2013 report by Hanover Research).

Derry Township District, Pennsylvania

In March 2011, Derry Township District formed a task force to explore the research on adolescent sleep and school start times. The task force announced six months later that the 7:38 a.m. high school start time would not be changed because of the potential costs of a start time change and disruptions to bus and family schedules. Another major concern was that student athletes and teachers who are high school athletic coaches would have to miss school to attend “away” games, since the school district would only have control over setting the times for “home” games (adapted from a 2013 report by Hanover Research).

Potential Implications of Delaying School Start Times

Below are some commonly identified challenges and concerns regarding a change in school start times:

1) **Transportation and Traffic Flow** (Kirby et al., 2011; CNMC's Blueprint for Change Team, 2014; National Sleep Foundation, 2011; Wolfson & Carksadon, 2005)
    - Because most school districts have bus transportations system designed to run as efficiently and inexpensively as possible, changes to school schedules could be greatly increase costs.
    - Rush hour congestion may become worse if school buses are on the road later in the morning and in the afternoon, though this is generally more of an issue in communities that are located in major metropolitan areas with more traffic congestion.

2) **After School Sports Practices and Games** (Jacob & Rockoff, 2011; National Sleep Foundation, 2011; Kirby et al., 2011; Wolfson & Carskadon, 2005)
    - Later school start times will affect after school sports in high schools. There may be less time to practice, or students could get home later from after school sports practice. Also, if other school districts do not change their start times, then some athletes may have to leave class early to attend a match or game. Later school start times could also leave less daylight hours for outside sports.
    - Some districts have rescheduled practice times, and others have installed lights so that practice can run later in the day. Yet others have coordinated student schedules so that students can have their "free" periods at the end of the day, giving them greater flexibility to participate in sports and other extracurricular activities during this time.
    - Also, if districts in the same region decide collectively to implement later school start times, then they can coordinate game/match times accordingly.

3) **Other After School Activities** (Kirby et al., 2011; National Sleep Foundation, 2011; Wolfson & Carskadon, 2005)
    - With later school start times, some students may find it difficult to participate in other extracurricular activities after school, such as music and sports lessons, etc.
    - Even if students could participate, they may get home later than they would have if schools were to end earlier in the day.

4) **Parents' Work Schedules** (CNMC's Blueprint for Change Team, 2014; Wrobel, 1999)
    - Parents who work may have to readjust their work schedules, and those who do not have that option may have to look for other jobs.

5) **Teachers' Work Schedules** (Kirby et al., 2011; CNMC's Blueprint for Change Team, 2014)
    - The work schedules of teachers as well as administrators and other staff may be disrupted.
    - There is a possibility that teachers and other staff may have less time to spend with their families, though presumably they would have more time in the morning to spend with families, prepare for the workday, and and/or sleep.

6) **Before or After School Childcare** (CNMC's Blueprint for Change Team, 2014; Wrobel, 1999)
    - Depending on the nature of the start time change, parents may have to arrange for before or after school childcare, which because of cost or availability, may not be an option for some.

7) **Students' After School Employment** (Kirby et al., 2011; National Sleep Foundation, 2011; Wrobel, 2011)
    - With later school start times, students who work after school may find that there are fewer hours available for them to work with later school start times.
    - Additionally, employers may be hesitant to hire students who cannot start working earlier in the day.

8) **Effects on Younger Students** (Jacob & Rockoff, 2011; Kirby et al., 2011; National Sleep Foundation, 2011; Wrobel, 2011)
    - If start times for elementary and high school students are switched, and elementary school students end up with the earliest start times, they may be walking to school or waiting for the bus in the morning when it is still dark.
    - In some families, older siblings provide interim supervision for younger siblings, which may not be an option with later high school start times. This could mean that some young children could be left unsupervised.

9) **Stress for Families** (National Sleep Foundation, 2011; Wrobel, 1999)
    - Many families have highly coordinated schedules, and changes to well-established routines can be unsettling to people.
    - Wrobel (1999) found that school districts that went to great lengths to involve the community and keep them informed well in advance of any changes to school start times reported less difficulty in making the necessary adjustments.

10) **Resistance of Students** (National Sleep Foundation, 2011; Wrobel, 1999)
    - Students may also be resistant to changes in their established routines, and some may express concern about having less time to do their homework, participate in after school activities, or socialize with friends.

The Differential Impact of Later School Start Times

It is important to note that a delay to school start times may not affect families and subsets of communities in the same way. Citing data from the Center for Applied Research and Education Improvement (CAREI) that looks at the impact of changes in school start times across school, community, and family contexts, Wrobel (1999) notes that "the impact of changing school start time is profound for many families" (p. 361). Families in the study experienced a wide range of both positive and negative effects. While some families reported little difficulty in adjusting to the new schedule, others were "devastated by the stress of attempting to meet the new demands on their time" (Wrobel, 1999, p. 361).

The study revealed clear differences based on household wealth and income on how families adjusted to the start time change. Affluent parents were more easily able to come up with alternative ways of

meeting new schedule demands (such as adjusting work schedules and finding daycare options), whereas families with limited resources had fewer options. For instance, in some families where older siblings who had previously supervised younger siblings were no longer available to babysit, there were concerns that young children would be left unsupervised—a concern that was not echoed by more affluent parents (Wrobel, 1999).

Wahlstrom's (2002) study, on the other hand, showed the different impact of a school start time change among suburban and urban parents. Parent survey data collected after the change in start time indicated that 92 percent of suburban parents supported the change, with parents' negative comments centered on the later time that children were coming home from sports or other after school activities. Urban parents' complaints related to changes in work schedules and transportation limitations that resulted from the start time change. On a more positive note, both urban and suburban parents noted that their high school children were "easier to live with" and found that they were having fewer confrontations in the morning about waking up and getting to school on time (Wahlstrom, 2002, p. 17-18).

Recommendations for School Administrators

Wolfson and Carskadon (2002) note the "tension between acting on facts and the politics that ensue in a discussion about changing school start times" as a key characteristic of this type of school reform effort and conclude that many districts have chosen not to change school start times due to fears of dividing communities (p. 19).

In light of the considerable challenges facing districts thinking about delaying start times, Wolfson and Carskadon (2005) make the following recommendations to school administrators (p. 57):

- Educate the community (students, parents, teachers, school nurses, guidance counselors, school board members) about adolescent sleep patterns and the importance of getting enough sleep
- Initiate a district-wide stakeholder assessment on school start times
- Consider a variety of school schedule options that will benefit adolescents' sleep and daytime functioning needs
- Develop a system for evaluating students for sleep disorders or poor sleep habits if they consistently fall asleep in class, are routinely late or absent from school, or are doing poorly academically
- Institute a sleep curriculum into middle and high school level health, biology, or other relevant courses
- Decrease nightly homework hours
- Buffer early start times by setting limits on evening activities at school as well as early morning and late evening athletic practices
- Counsel students and families on planning activities around an agenda that has adequate sleep at its core
- Set an example for making sleep a positive priority

Highlights from CNMC's Blueprint for Change Team Report

The CNMC's Blueprint for Change Team (2014) notes that approximately 70 school districts and 1,000 schools in the U.S. have implemented later high school start times in response to the growing scientific evidence about the negative academic and health-related outcomes associated with chronic sleep loss. Their report offers an in-depth examination of the process by which school districts consider, approve, and implement changes in school start times and serves as a valuable resource for districts that are considering a start time change.

The report provides in-depth case studies of school districts that have successfully delayed start times (a few of which were cited earlier) and results from a web-based survey with school districts and interviews and discussions with sleep experts, parents, and school officials. In addition, it presents a summary grid of selected schools that have delayed start times along with a summary of the lessons learned from other districts. There is also a historical timeline of school start time change and advances in knowledge of sleep and circadian biology in the Appendix.

In this section, I will outline some of the observations and general trends from the summary grid of schools and provide highlights from the summary of the lessons learned as presented in the report.

Summary Grid of Schools that have Delayed Start Times

CNMC's Blueprint for Change Team (2014) presents a summary grid of select schools that have delayed start times with demographics, change strategies employed, and additional comments (see p. 6-10). Here are some observations and general trends regarding the 38 school districts they profiled:

- **Regarding the Start Time Change**
    - Eight districts (or 21 percent) changed to a start time between 7:30 to 8:00 a.m.
    - Eleven districts (or 29 percent) changed to a start time between 8:00 to 8:30 a.m.
    - Fourteen districts (or 37 percent) changed to a start time between 8:30 to 9:00 a.m.
    - Five districts (or 13 percent) changed to a start time between 9:00 to 9:30 a.m.
- **Regarding the Size of the Districts**
    - Seventeen districts (or 45 percent) had a student population that was under 10,000
    - Thirteen districts (or 34 percent) had a student population that between 10,000 and 39,999
    - Five districts (or 13 percent) had a student population that was between 40,000 and 69,999
    - Three districts (or 8 percent) had a student population of 70,000 or more
- **Regarding the Change Strategies Employed**
    - Eleven districts (or 29 percent) decided to flip school schedules in some way
        - HS/ES flip (5 districts)
        - HS/MS flip (3 districts)
        - HS/MS with ES (2 districts)
        - MS/ES with HS (1 district)

- Twenty-one districts (or 55 percent) implemented a shift in high school start times (without instituting a flip in school schedules)
  - HS/MS/ES shifted later (4 districts)
  - HS/MS shifted later (7 districts)
  - Only HS shifted later (10 districts)
- Three districts (or 8 percent) decided to implement a pilot study/program
- Two districts (or 5 percent) decided to implement flexible start times

Summary of Lessons Learned

CNMC's Blueprint for Change Team (2014) also presents a summary of lessons learned from other school districts that have delayed school start times (see p. 25-29).

1) The Importance of Leadership

- The leadership of the district superintendent is crucial as to whether or not a school district is successful in changing school start times, as is support from the school board.
- "Those school districts that seemed to have been most successful in changing their start times are those in which the superintendent, district staff and the school board have become well-informed regarding the sleep science and have worked with key community organizations to address logistical challenges and study the truly relevant logistical or financial concerns or issues and to promote the benefits to student health, safety, and academic and athletic performance" (p. 25).

2) Education of the Entire Community

- Stakeholders should be knowledgeable about the research on adolescent sleep patterns and needs to effectively communicate the rationale for changing school start times and to refute misconceptions.
- The health and safety benefits associated with adolescents getting adequate sleep should be emphasized, and efforts should be made to work with local sleep centers and hospitals to provide medically accurate information to the public.
- Teachers and other school personnel, including health and counseling professionals, should be informed about the issue, and schools should consider integrating sleep-related education into curricula so students can learn about the importance of sleep to their overall health.
- It is important that information be provided to families in culturally sensitive ways (by translating print educational materials into multiple languages, providing translation services at community meetings, etc.).

3) Consensus Building among Stakeholders

- It is important to inform and engage all stakeholders, including community members, organizations that use district facilities, and programs and agencies that provide services to students, early in the process to understand concerns and to seek a consensus on solutions.
- Districts should notify these groups of any decisions made regarding school start times as soon as possible so that there is sufficient time to adjust to the changes.

- Districts should consider the views of teachers and other school staff and develop policies that help teachers and staff adapt to the changes.
- It is important to involve principals from high schools, middle schools, *and* elementary schools because it is likely that all schools and students in the district will be impacted to some degree.
- Engagement of students is also critical in garnering support for the change.
- When considering start time changes, districts should first bring together staff representing key areas such as transportation, curriculum, special or health services, and athletics to do their own fact-finding; in this way, they can work toward identifying logistical issues early on and begin developing potential solutions before opening up the discussion to the wider community.
- It may also be beneficial to engage the leadership of key community groups in face-to-face meetings to build trust, air mutual concerns, and establish an open dialogue prior to establishing working groups or task forces.

4) Transportation as a Major Logistical and Cost Factor

- Transportation of students determines most start time schedules and is typically the largest cost and logistical factor that districts consider.
- Districts that already employ a multi-tiered delivery schedule may have to use more creative strategies to find transportation savings.
- A common strategy used to overcome potential transportation costs is “flipping” school schedules (i.e., flipping HS and ES times or HS and MS times, etc.)
- For some districts, new approaches should be considered. These include encouraging car pools, providing incentives for using public transportation, charging a flat-rate transportation fee to students for special activities, and allowing middle school and high school students to ride on the same buses.

5) Athletics and Community Use of Recreational Facilities

- Community members in districts contemplating school start time changes are frequently concerned about impact on after school sports practices and games.
- The CNMC Blueprint for Change Team (2014) did not come across districts in which athletic programs were cancelled or adversely affected in any major way following start time changes. In fact, some districts found that more students participated in athletics, and that sports programs grew and teams performed better after high school start times were changed.
- It is also important for administration officials, coaches, and student athletes to understand the negative effects of chronic sleep loss not only on health and academic achievement but also on athletic performance and safety (i.e., the relationship between inadequate sleep and increased sport-related injuries).

6) One Size Does Not Fit All

- While there are lessons to be learned from communities that have chosen to implement later school start times, it is important to note that each community is unique, and there is no “one-size-fits-all” solution in addressing this issue.
- Among the many factors that need to be considered are student commute times, the number and length of school bus routes, the availability of public transportation, traffic patterns, community use of school facilities, the number of students enrolled in free

breakfast programs, and the impact of later dismissal times on after school programs and activities.

7) Prioritizing Sleep Health is an Important Corollary to School Start Time Change

- Even after school start times are changed and despite the many benefits associated with adolescents getting more sleep, there will be families and students who choose not to take advantage of the additional sleep opportunity. Accordingly, the importance of providing education about the importance of getting adequate sleep in conjunction with schedule changes cannot be understated.
- It is important that districts and schools not undermine the benefits of delayed start times by rescheduling sports and other after school programs before school. Excessive homework may also prevent students from getting the sleep they need.
- "Districts should consider using the change in start times as an opportunity to make other adjustments that are in the best health interests of students and which complement the benefits associated with increased sleep" (p. 28).

8) Adjustments Take Time

- It is critical to provide sufficient time prior to implementing changes to school start times to allow families and other community members to make necessary plans related to child care, transportation, and family time.
- Once finalized, districts should communicate the details of the changes, along with the rationale and decision-making process behind the changes, as soon as possible.
- Timely and effective communication and outreach efforts are necessary to address the misinformation and misconceptions that may circulate around such an important school policy change.

9) Anticipation is Often Worse than the Reality

- Similar to concerns regarding the impact of delayed start and dismissal times on athletic practices and games, many other potential problems raised by communities prior to the change are often not substantiated as families and communities make adjustments to accommodate changes in schedules.
- Some problems may resolve on their own over time. For example, traffic may get worse when bus routes and schedules are changed, but this is often temporary as bus drivers become more accustomed to their new routes and schedules.

10) Monitoring Outcomes

- Districts should monitor the results and outcomes following a start time change, communicate positive results to the community, and seek ways to address negative or unforeseen impacts. Toward this end, districts should consider working with outside partners, such as hospitals and universities, to design pre- and post-surveys to measure the impact of changing school start times on student health, safety, and academics.
- Districts that conduct outcomes research and communicate those findings to the community establish further acceptance of and support for later school start times. Some have also contributed to the growing academic literature in this area.

References

American Academy of Pediatrics. (2014). School start times for adolescents. *Pediatrics*, 134(3), 642-649. doi:10.1542/peds.2014-1697

Beebe, D. W. (2011). Cognitive, behavioral, and functional consequences of inadequate sleep in children and adolescents. *Pediatric Clinics of North America*, 58(3), 649-665. doi:10.1016/j.pcl.2011.03.002

Borbély, A. A. (192). A two process model of sleep regulation. *Human Neurobiology*, 1(3), 195-204.

Calamaro, C. J., Park, S., Mason, T. B. A., Marcus, C. L., Weaver, T. E., Pack, A., & Ratcliffe, S. J. (2010). Shortened sleep duration does not predict obesity in adolescents. *Journal of Sleep Research*, 19(4), 559-566. doi:10.1111/j.1365-2869.2010.00840.x

Cappuccio, F. P., Taggart, F. M., Kandala, N., Currie, A., Peile, E., Stranges, S., & Miller, M. A. (2008). Meta-analysis of short sleep duration and obesity in children and adults. *SLEEP*, 31(5), 619-626.

Carrell, S. E., Maghakian, T., and West, J. E. (2011). A's from Zzzz's? The causal effect of school start time on the academic achievement of adolescents. *American Economic Journal: Economic Policy*, 3, 62-81. http://www.aeaweb.org/articles.php?doi=10.1257/pol.3.3.62

Carskadon, M. A., Acebo, C., & Jenni, O. G. (2004). Regulation of adolescent sleep: Implications for behavior. *Annals of the New York Academy of Sciences*, 1021, 276-291. doi: 10.1196/ annals.1308.032

Carskadon, M. A., Acebo, C., Richardson, G. S., Tate, B. A., & Seifer, R. (1997). An approach to studying circadian rhythms of adolescent humans. *Journal of Biological Rhythms*, 12(3), 278-289. doi: 10.1177/ 074873049701200309

Carskadon, M. A., Vieira, C., & Acebo, C. (1993). Association between puberty and delayed phase preference. *SLEEP*, 16(3), 258-262.

Carskadon, M. A., Wolfson, A. R., Acebo, C., Tzischinsky, O., & Seifer, R. (1998). Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days. *SLEEP*, 21(8), 871-881.

Chen, X., Beydoun, M. A., & Wang, Y. (2008). Is sleep duration associated with childhood obesity? A systematic review and meta-analysis. Obesity, 16(2), 265-274. doi:10.1038/oby.2007.63

Children's National Medical Center's Blueprint for Change Team. (2014). *School start time change: An in-depth examination of school districts in the United States*. Washington, DC: Children's National Medical Center.

Crowley, S. J., Acebo, C., & Carskadon, M. A. (2007). Sleep, circadian rhythms, and delayed phase in adolescence. *Sleep Medicine*, 8, 602–612.

Curcio, G., Ferrara, M., & De Gennaro, L. (2006). Sleep loss, learning capacity and academic performance *Sleep Medicine Reviews*, 10, 323–337.

Danner, F., & Phillips, B. (2008). Adolescent sleep, school start times, and teen motor vehicle crashes. *Journal of Clinical Sleep Medicine*, 4(6), 533- 535.

Dahl, R. E. (1996). The impact of inadequate sleep on children's daytime cognitive function. *Seminars in Pediatric Neurology*, 3(1), 44-50. http://dx.doi.org/10.1016/S1071-9091(96)80028-3

Dahl, R. E., & Lewin, D. S. (2002). Pathways to adolescent health sleep regulation and behavior. *Journal of Adolescent Health*, 31(6), 175-184.

Dewald, J. F., Meijer, A. M., Oort, F. J., Kerkhof, G. A., & Bogels, S. M. (2010). The influence of sleep quality, sleep duration, and sleepiness on school performance in children and adults: A meta-analytic review. *Sleep Medicine Reviews*, 14, 179-189.

Edwards, F. (2012). Early to rise? The effect of daily start times on academic performance. *Economics of Education Review*, 31, 970-983.

Fallone, G., Owens, J. A., & Deane, J. (2002). Sleepiness in children and adolescents: Clinical implications. Sleep Medicine Review, 6(4), 287-306.

Fairfax County Public Schools. (2014). Later high school start times. Retrieved from http://www.fcps.edu/news/starttimes.shtml

Fitzgerald, C. T., Messias, E., & Buysse, D. J. (2011). Teen sleep and suicidality: Results from the youth risk behavior surveys of 2007 and 2009. *Journal of Clinical Sleep Medicine*, 7(4), 351-356.

Goldstein, T. R., Bridge, J. A., & Brent, D. A. (2008). Sleep disturbance preceding completed suicide in adolescents. *Journal of Consulting and Clinical Psychology*, 76(1): 84-91. doi:10.1037/0022-006X.76.1.84

Gruber, R., Cassoff, J., Frenette, S., Wiebe, S., & Carrier, J. (2012). Impact of sleep extension and restriction on children's emotional lability and impulsivity. *Pediatrics*, 130(5), e1155-e1161.

Hagenauer, M. H., Perryman, J. I., Lee, T. M., & Carskadon, M. A. (2009). Adolescent changes in the homeostatic and circadian regulation of sleep. *Developmental Neuroscience*, 31(4), 276-284. doi: 10.1159/000216538

Hanover Research. (2013). *Impact of school start time on student learning*. Washington, DC: Hanover Research, District Administration Practice.

Hansen, M., Janssen, I., Schiff, A., Zee, P. C., & Dubocovich, M. L. (2005). The impact of school daily schedule on adolescent sleep. *Pediatrics*, 115(6), 1555-1561. doi: 10.1542/peds.2004-1649

Hinrichs, P. (2011). When the bell tolls: The effects of school starting times on academic achievement. *Education Finance and Policy*, 6(4), 486-507.

Jacob, B. A., & Rockoff, J. E. (2011). *Organizing schools to improve student achievement: Start times, grade configurations, and teacher assignments*. Washington, DC: The Hamilton Project, Brookings.

Jenni, O.G., Achermann, P., Carskadon, M.A. (2005). Homeostatic sleep regulation in adolescents. *SLEEP*, 28(11), 1446-1454.

Kelley, P., Lockley, S. W., Foster, R. G., & Kelley, J. (2014). Synchronizing education to adolescent biology: Let teens sleep, start school later. *Learning, Media and Technology*, 1-17. http://dx.doi.org/10.1080/17439884.2014.942666

Leproult, R., & Van Cauter, E. (2010). Role of sleep and sleep loss in hormonal release and metabolism. *Endocrine Development*, 17, 11-21. doi:10.1159/000262524

Liu, X. (2004). Sleep and adolescent suicidal behavior. *Sleep*, 1(7), 1351-1358.

Lufi D; Tzischinsky O; Hadar S. (2011). Delaying school starting time by one hour: Some effects on attention levels in adolescents. *Journal of Clinical Sleep Medicine*, 7(2), 137-143.

Lytle, L. A., Murray, D. M., Laska, M. N., Pasch, K., Anderson, S. E., & Farbakhsh, K. (2013). Examining the longitudinal relationship between change in sleep and obesity risk in adolescents. *Health Education & Behavior*, 40(3), 362-370. doi:10.1177/1090198112451446

Marshall, N. S., Glozier, N., & Grunstein, R. R. (2008). Is sleep duration related to obesity? A critical review of the epidemiological evidence. *Sleep Medicine Reviews*, 12, 289-298.

Matricciani, L. A., Olds, T. S., Blunden, S., Rigney, G., & Williams, M. T. (2012). Never enough sleep: A brief history of sleep recommendations for children. *Pediatric*s, 129, 548–556.

Moore, M., Kirchner, H., Drotar, D., Johnson, N., Rosen, C., Ancoli-Israel, S., & Redline, S. (2009). Relationships among sleepiness, sleep time, and psychological functioning in adolescents. *Journal of Pediatric Psychology*, 34(10), 1175–1183. doi:10.1093/jpepsy/jsp039

Moore, M., & Meltzer, L. J. (2008). The sleepy adolescent: Causes and consequences of sleepiness in teens. *Paediatric Respiratory Reviews*, 9(2), 114-120.

National Sleep Foundation. (2006). 2006 National Sleep in America Poll: Highlights and key findings. Retrieved from http://sleepfoundation.org/sites/default/files/Highlights_facts_06.pdf

National Sleep Foundation. (2011). Eight major obstacles to delaying school start times. Retrieved from http://sleepfoundation.org/sleep-news/eight-major-obstacles-delaying-school-start-times

O'Brien, L. M. 2009. The neurocognitive effects of sleep disruption in children and adolescents. *Child and Adolescent Psychiatric Clinics in North America*, 18, 813-823.

O'Brien, E. M., & Mindell, J. A. (2005). Sleep and risk-taking behavior in adolescents. *Behavioral Sleep Medicine*, 3(3), 113-133.

Owens, J. A., Belon, K., & Moss, P. (2010). Impact of delaying school start time on adolescent sleep, mood, and behavior. *Archives of Pediatrics and Adolescent Medicine,* 164(7), 608-614.

Pagel, J. F., Forister, N., & Kwiatkowki, C. (2007). Adolescent sleep disturbance and school performance: The confounding variable of socioeconomics. *Journal of Clinical Sleep Medicine*, 3(1), 19-23.

Park, S. (2011). Association between short sleep duration and obesity among South Korean adolescents. *Western Journal of Nursing Research*, 33(2), 207-223.

Pasch, K. E., Laska, M. N, Lytle, L. A., & Moe, S. G. (2010). Adolescent sleep, risk behaviors, and depressive symptoms: Are they linked? *American Journal of Health Behavior*, 34(2), 237-248.

Pasch, K. E., Latimer, L. A., Cance, J. D., Moe, S. G., & Lytle, L. A. (2012). Longitudinal bi-directional relationships between sleep and youth substance use. *Journal of Youth and Adolescence*, 41(9), 1184-1196. doi:10.1007/s10964-012-9784-5

Roberts, R. E., & Duong, H. T. (2013). Depression and insomnia among adolescents: A prospective perspective. *Journal of Affective Disorders*, 148(1): 66–71. doi:10.1016/j.jad.2012.11.049

Roberts, R. E., Roberts, C. R., & Duong, H. T. (2009). Sleepless in adolescence: Prospective data on sleep deprivation, health and functioning. *Journal of Adolescence*, 32(5), 1045–1057. doi:10.1016/j.adolescence.2009.03.007

Shochat, T., Cohen-Zion, M., & Tzischinsky, O. (2014). Functional consequences of inadequate sleep in adolescents: A systematic review. *Sleep Medicine Review*, 18(1), 75-87. doi:10.1016/ j.smrv.2013.03.005

Snell, E. K., Adam, E. K., & Duncan, G. J. (2007). Sleep and the body mass index and overweight status of children and adolescents. *Child Development*, 78(1), 309-323.

Taheri, S. (2006). The link between short sleep duration and obesity: We should recommend more sleep to prevent obesity. *Archives of Disease in Child*, 91(11), 881-884.

Taheri, S., Lin, L., Austin, D., Young, T., & Mignot, E. (2004). Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. *PLoS Medicine*, 1(3), 210-217. doi:10.1371/journal.pmed.0010062

Taylor, D. J., Jenni, O. G., Acebo, C., & Carskadon, M. A. (2005). Sleep tendency during extended wakefulness: Insights into adolescent sleep regulation and behavior. *Journal of Sleep Research*, 14(3), 239-244.

Vorona, R. D., Szklo-Coxe, M., Wu, A., Dubik, M., Zhao, Y., & Ware, J. C. (2011). Dissimilar teen crash rates in two neighboring southeastern Virginia cities with different high school start times. *Journal of Clinical Sleep Medicine*, 7(2), 145-151.

Wahlstrom, K. (2002). Changing times: Findings from the first longitudinal study of later high school start times. *NASSP Bulletin*, 86(633), 3-21.

Wahlstrom, K., Dretzke, B., Gordon, M., Peterson, K., Edwards, K., & Gdula, J. (2014). *Examining the impact of later school start times on the health and academic performance of high school students: A multi-site study*. Center for Applied Research and Educational Improvement. St Paul, MN: University of Minnesota.

Winsler, A., Deutsch, A., Vorona, R. D., Payne, P. A., & Szklo-Coxe, M. (2014). Sleepless in Fairfax: The difference one more hour of sleep can make for teen hopelessness, suicidal ideation, and substance use. *Journal of Youth Adolescence*, Sep 2 (Epub ahead of print).

Wolfson, A. R., & Carskadon, M. A. (1998). Sleep schedules and daytime functioning in adolescents. *Child Development*, 69(4), 875-887.

Wolfson, A. R., & Carskadon, M. A. (2005). A survey of factors influencing high school start times. *NASSP Bulletin*, 89(642), 47-66. doi: 10.1177/019263650508964205

Wolfson, A. R., & Carskadon, M. A. (2003). Understanding adolescents' sleep patterns and school performance: A critical appraisal. *Sleep Medicine Review*, 7(6), 491-506.

Wong, M. M., Brower, K. J., Fitzgerald, H. E., & Zucker, R. A. (2004). Sleep problems in early childhood and early onset of alcohol and other drug use in adolescence. *Alcoholism: Clinical and Experimental Research*, 28(4), 578-587.

Wong, M. M., Brower, K. J., Nigg, J. T., & Zucker, R. A. (2010). Childhood sleep problems, response inhibition, and alcohol and drug outcomes in adolescence and young adulthood. *Alcoholism: Clinical and Experimental Research*, 34(6), 1033-1044.