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Examining the Impact of Later High School Start Times on the Health and Academic Performance of High School Students: A Multi-Site Study

Major findings: *The results from this three-year research study, conducted with over 9,000 students in eight public high schools in three states, reveal that high schools that start at 8:30 AM or later allow for more than 60% of students to obtain at least eight hours of sleep per school night. Teens getting less than eight hours of sleep reported significantly higher depression symptoms, greater use of caffeine, and are at greater risk for making poor choices for substance use. Academic performance outcomes, including grades earned in core subject areas of math, English, science and social studies, plus performance on state and national achievement tests, attendance rates and reduced tardiness show significantly positive improvement with the later start times of 8:35 AM or later. Finally, the number of car crashes for teen drivers from 16 to 18 years of age was significantly reduced by 70% when a school shifted start times from 7:35 AM to 8:55 AM.*

INTRODUCTION

High school students often seem to stay up too late at night and then have difficulty getting out of bed the next morning. Although there might be social and environmental factors that influence adolescents' sleep behavior, recent research on the sleep-wake cycle of teens has identified changes in specific biological processes that occur with the onset of puberty that cause adolescents not only to need more sleep but also to feel sleepy at a later time (e.g., Crowley, Acebo, & Carskadon, 2007). Because the sleep-wake cycle changes as children grow into adolescents, early high school start time has been identified as an important external factor that could restrict sleep and negatively affect academic learning (e.g., Owens, Belon, & Moss, 2010).

STUDY OVERVIEW

This research project examined whether or not a delay in start time for high school students had an impact on their overall health and academic performance. Data were collected in eight public high schools in five school districts in three states—Minnesota, Colorado, and Wyoming. The population was ethnically and socio-economically diverse. Percentages of white students ranged from 60% to 90%, the free/reduced lunch rate ranged from 34% to 10%, and the graduation rates ranged from 81% to 97%.

The research study consisted of three parts. Part 1 of the study involved collecting survey data from over 9,000 students across eight high schools in five school districts. Students were individually surveyed about their daily activities, substance use, and sleep habits. We examined various health factors post-start time delay, plus we compared them with national average data from other studies. In Part 2 of the study, we collected data regarding students' academic performance, such as grades earned, attendance, tardiness, and performance on state and national tests. We also examined car crash data for the communities involved in this project. Part 3 of the research included an examination of the processes by which local school districts made the decision to change to a later start time. Interviews with key players who were active participants in the discussions and in the decisions for each of the five districts identified both the barriers and facilitative aspects in making such a policy change.

Overview of Factors Related to Sleep in Adolescence

While all of the benefits of sleep are not yet clear, the fact that all animals do sleep indicates its importance (Tononi & Cirelli, 2013; Tononi & Cirelli, 2005). Sleep appears to help with the encoding of memories and learning (Carskadon, 2011a; Payne, 2011; Tononi & Cirelli, 2013; Tononi & Cirelli, 2006), ability to pay attention (Beebe, 2011; Beebe, Rose, & Amin, 2010), emotional regulation (Dahl, 1999) and other health benefits such as lower prevalence of mood disorders (Harvey, Alfano & Clarke, in press). Additionally, evidence of higher sleep amounts in younger animals suggests that sleep plays an important role during the maturational process (Dahl, 1999). Given that adolescence is a time of great biological change, it is necessary to consider the importance of getting enough sleep in this developmental period.

Although many believe that the amount of sleep needed decreases as a child enters adolescence, research has shown that adolescents still need the same amount of sleep or more (Carskadon, 2013; Carskadon, Acebo, & Jenni, 2004). While an estimated 9 hours 20 minutes may be ideal for adolescents (Carskadon, 2013), results from many studies have found that, on average, adolescents report sleeping less than 8 hours on school nights (Carskadon, 2011b; Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998; Dexter, 2003; Eliasson, Eliasson, King, Gould, & Eliasson, 2002; National Sleep Foundation, 2006; Wahlstrom, 2002). While students tend to report longer amounts of sleep on weekends, typically believed to be due to attempting to "catch up" from inadequate sleep during the school week, there are still detrimental effects due to the insufficient sleep on school nights (Andrade, Benedito-Silva, Domenice, Arnhold & Menna-Barreto, 1993; Dahl & Lewin, 2002; Wahlstrom, 2002). Given the negative effects, it is important to consider why adolescents tend to be sleep deprived.

Factors Influencing Amount of Sleep

Adolescence brings changes in a child's life due to a number of biological changes and psychosocial factors. Not only are children going through puberty, they are also experiencing more independence through choice of after school activities, driving, after school jobs, and other responsibilities, as well as more peer influence on their thoughts and behavior.

Biological changes. Aside from physiological changes associated with puberty, changes in natural sleep time preference occurs in adolescence (Crowley, Acebo, & Carskadon, 2007; Hagenauer, Perryman, Lee, & Carskadon, 2009). As children reach more advanced stages of physical puberty, the changes in the sleep

patterns become more pronounced (Carskadon, 1999). Sleep patterns are influenced by two competing, yet compatible processes known as the circadian rhythm (Process C) and homeostasis (Process S) (Crowley, Acebo, & Carskadon, 2007; Hagenauer, Perryman, Lee, & Carskadon, 2009).

Process S can be thought of as a measure of sleep pressure. That is, when one has been awake for a while, the pressure to sleep becomes greater; however, if one has been sleeping for some time, the pressure to sleep lessens. Process C, on the other hand, can be thought of more as a biological clock that lets us know when sleep should occur. This feeling of when sleep should occur is related to when the body is exposed to light as well as when secretion of a chemical known as melatonin occurs. As children mature, the timing of melatonin secretion becomes later in the evening (Tarokh & Carskadon, 2009), known as a phase delay. It has been shown that the pressure to fall asleep tends to become lower as a child enters adolescence (Carskadon, Acebo, & Jenni, 2004; Carskadon, 2011b). This, in combination with the natural phase delay in the circadian rhythm can help to explain why sleeping patterns change with puberty. This phase delay has been seen in other types of mammals at puberty, which provides further evidence of the shift in circadian phase seen in humans being purely biological (Hagenauer et al., 2009). However, the reason adolescents tend to have insufficient sleep is not solely due to their body's natural changes, but also due to an interaction with societal expectations and norms.

Societal expectations. One of the most commonly cited and researched societal factors influencing adolescent sleep is that of school start times. In the United States in particular, as students get older, school start times tend to be earlier (Wolfson & Carskadon, 2005). However, this pattern of earlier morning obligations is in direct opposition to the students' natural sleep patterns. It has repeatedly been shown that when middle or high school start times are pushed later, students still tend to go to bed about the same time, but, due to waking up later, increase their sleep (Carskadon et al., 1998; Veda, Saxvig & Wilhelmsen-Langeland, Wahlstrom, 2002). While the benefits to later school start times are undeniable regarding amount of sleep students get, there are many other factors which must be considered. When schools change their schedules, transportation to and from school and school activities can be affected in a variety of ways. For instance, many school districts use the same buses to serve multiple schools. If the start times of some schools are delayed, it is possible that the change would force other schools to start earlier in order to allow for all necessary busing to occur. Typically, this would mean that younger students would have to catch the bus at an earlier time, which may mean more time spent waiting in the dark (Wrobel, 1999; Wahlstrom, 2002; Wolfson & Carskadon, 2005). If the younger children are also beginning earlier than the adolescents, this can mean that older children are no longer available for after school care for their younger siblings. A similar problem with parent work schedules and providing transportation and child care could occur with a change in school start times (Wrobel, 1999).

Delaying the start time of schools may affect after school activities, such as sports, because school end times are delayed as well. With sports schedules dependent on other school schedules, more time in the afternoon classes may have to be missed by some students in order to allow them to participate in sports games. The amount of time that students would have available for after school jobs may also become less, which could be problematic for families that rely on adolescent income for everyday living (Wolfson & Carskadon, 2005; Wrobel, 1999). That said, the study by Wahlstrom (2002) found there was no negative impact on after school employment of high school students whose schools shifted to later start times

because all employers who were interviewed indicated that their need for additional staff did not occur until 4:00 PM or later.

While changing school start times can negatively impact ability to participate in after school activities, the increased need for social activities in adolescence may be related to insufficient sleep as well. Students not only want to participate in social activities, but also must complete daily homework assignments. Some students may sacrifice sleep in order to be able to complete both types of activities.

Use of technology. In adolescence, there is increased reliance on technology for social interactions as well as increased availability of technology (National Sleep Foundation, 2006). Negative effects of nighttime use of computers or watching TV, such as difficulty falling asleep (Polos et al., 2010; Shochat, Flint-Bretler, & Tzischinsky, 2010), as well as problems with mood, behavior, and cognitive functioning during the day have been reported (Polos et al., 2010). Many students with technology in their bedrooms report frequent awakening at night due to receiving a text, phone call, or email (Harvey et al., in press).

Light exposure. As mentioned above, the circadian rhythm is influenced in part by exposure to light. This light can either be natural, as from the sun, or artificial, as from electronics such as a computer or TV. Thus, adolescents who report using an electronic device which emits light, in particular blue light, shortly before bed may be artificially affecting their bodies' natural sleep rhythm (Calamaro et al., 2009; Carskadon, 2013). While light exposure in the morning helps adults to awaken more easily, there is some evidence that this facilitating factor is diminished in adolescence (Hansen et al., 2005) while the effect of evening light exposure inhibiting sleep may be enhanced (Carskadon, Acebo, & Jenni, 2004).

Caffeine. Another known inhibitor of sleep is the consumption of caffeine. Not only is drinking soda prevalent in adolescence, energy drinks high in caffeine content, as well as coffee and tea, are also consumed (Calamaro, Mason, & Ratcliffe, 2009; Ludden & Wolfson, 2009; Pollak & Bright, 2003). Because caffeine is known to reduce sleep pressure, it is no surprise that studies looking at adolescent consumption find that students who have more caffeinated drinks slept less overall (Ludden & Wolfson, 2009; Pollak & Bright, 2003) and tend to have a harder time staying awake at school (Calamaro et al., 2009; Ludden & Wolfson, 2009).

Consequences of Not Enough Sleep

Mental health and behavioral outcomes. Sleep problems in childhood are known to be predictive of the development of anxiety and depressive symptoms as the child matures (Beebe, 2011). This negative effect of sleep problems appears to carry on into adolescence, where teens are more likely to have lower self-esteem (Fredriksen, Rhodes, Reddy & Way, 2004), have a more negative attitude towards life (Perkinson-Gloor, Lemola, & Grob, 2013), more problems regulating their emotions (Dahl, 1999; Dahl & Lewin, 2002), higher rates of mood disorders (Harvey et al., in press), and thoughts of suicide (Fitzgerald, Messias, & Buysse, 2011).

However, mood disorders such as depression or bipolar disorder are considered to have a bidirectional causal influence with sleep (Harvey et al., in press). That is, people with depression tend to have more sleep problems, but people with more sleep problems also tend to be more likely to be depressed. A bidirectional causal relationship between sleep and suicidality may also exist (Fitzgerald et al., 2011; Gau et al., 2007), revealing the difficulty of interpreting the interaction between sleep, depressive symptoms, and thoughts of suicide.

High risk behaviors. Many people who have mood disorders such as depression also tend to use drugs and alcohol more (Harvey et al., in press). Teens who report having insufficient sleep have been found to be more likely to smoke cigarettes, use marijuana, engage in sexual activity, and drink alcohol (McKnight-Eily et al., 2011; Dahl & Lewin, 2002). Furthermore, older adolescents and college students who are at the late end of the morningness-eveningness continuum are more likely to habitually use drugs and alcohol (Gau et al., 2007; Onyper, Tacher, Gilber, & Gradess, 2012).

Attention problems. Ability to focus is important not only for learning of new information, but also for safe completion of activities such as driving. The level of inattentive behavior has been found to be higher for students who have had less sleep (Beebe et al., 2010; Lufi, Tzischinsky, & Hadar, 2011). Additionally, reaction times improve in students who have had more sleep (Lufi et al., 2011; Vedaa et al., 2012). Given that reaction time is an important factor when driving in order to avoid having an accident, it is no surprise that there is a high prevalence of teen automobile accidents.

Lower quality sleep has been shown to be associated with higher prevalence of self-reported accidents among teen drivers (Pizza et al., 2010), as well as lower quantity (Danner & Phillips, 2008). A study that used DMV records of teen automobile accidents found that adolescent automobile accidents occurred at a higher rate in a city which had an earlier high school start time than its neighboring, but demographically similar city (Vorona et al., 2011). Because of the extensive research indicating that students who start school later get more sleep, it may be reasonable to assume that this difference in crash rates is in part due to differences in sleep amounts for teens in the two cities.

Academics. While the evidence pertaining to consequences of not enough sleep in adolescents as related to academic outcomes (grades, test scores, attendance) is still emerging, the general consensus of research indicates that good sleep has a positive relationship with academic outcomes for students in middle school all the way through college (Wolfson & Carskadon, 2003; Edwards, 2012; Wahlstrom, 2002; Carrell, Maghakian, & West, 2011). Additionally, if students do not obtain enough sleep before beginning their school day, they will have more difficulty understanding material taught that day and struggle to complete an assignment or test, regardless of the amount of time spent studying (Gillen-O'Neel, Huynh, & Fuligni, 2013).

Studies have shown when school start times are pushed back, an increase in amount of sleep, as well as attendance and decrease in tardies to first period are observed (Drake et al., 2003; Wahlstrom, 2002). While some studies do not report a significant relationship between grade point average (GPA) and amount of sleep (Eliasson et al., 2002; Wahlstrom, 2002; Fredriksen et al., 2004), studies where the variables in the methodology could be adequately controlled do show a relationship between amount of sleep and GPA (Carrell et al., 2011; Perkinson-Gloor et al., 2013). In studies that examined subject areas independently, mathematics grades appear to be more related to amount of sleep obtained than other core courses (Ng, Ng, & Chan, 2009). As with grades, there are inconsistent results in studies that examined changes in test scores related to more sleep, with some reporting a positive effect (Edwards, 2012; Carrell, 2011) and others reporting no effect (Hinrichs, 2012). However, as with the studies looking at grades, those which found significant, positive relationships used stronger and more valid methodology to assess the relationship between sleep and test scores.

It is known that people who consider themselves as “morning people” show their best performance earlier in the day, with performance decreasing as the day continues. On the other hand, evening types tend to

show greater performance throughout the day (Anderson et al., 1991). One possible explanation for the lack of academic effects found in some studies is that most adolescents tend to shift towards being evening types (Randler & Frech, 2009) and tend to show optimal performance on tasks later in the day (Hansen et al., 2005; Kirby, Maggi, & D'Angiulli, 2011). Therefore, studies which look at differences in academic tests such as the ACT which are typically given in the morning (e.g., Hinrichs, 2011) may not be controlling for the confounding factor of the time of day that the assessment is given.

To summarize, sleep plays an important role in all aspects of an adolescent's life. Insufficient sleep can be related to attention problems both in and out of school, general cognitive functioning, emotional regulation, mood disorders, engaging in risky behaviors, and academic outcomes. Therefore, it is important that school personnel, parents, and students alike understand and make choices using the knowledge that we have about sleep both as a framework and a lens.

Academic Performance Outcomes

Minnesota, Colorado, and Wyoming School Districts Academic Results

Data Collection and Analysis Methods

The research question addressed in this part of the study was: What are the pre-post start time delay differences in academic outcomes? This question is notable in that identifying and then locating specific outcome variables across two or more school systems is an enormous challenge. Every district has its own data system containing data fields for student attendance and achievement data that are often not comparable from one district to another. Defining or operationalizing each variable to allow for comparison across districts required many conversations among the research team and the database specialists in each of the districts participating in this study. As a result, we had to clarify exactly what was comparable before we conducted our analyses, and we arrived at a list of commonly defined variables for pre-post examination across the districts, including:

- Attendance rate
- Excused and unexcused absences
- Tardiness
- Overall grade point average (GPA)
- Grades earned in core subject areas of English, math, social studies, and science in 1st- and 3rd-period classes
- Standardized test performance

Additionally, because of when the data were collected it was not possible to complete all desired comparisons. All significant results based on analyses that could be completed can be found in Appendix C. Although the same comparisons could not be made across all schools and districts, there were some

general patterns noticeable in the data. Analysis was conducted for both independent groups (i.e., students grouped by grade level) and dependent groups (i.e., comparing the same students from year to year).

Attendance and Tardies

Although results regarding attendance rate changes were not consistent across schools or even within schools, most schools and districts saw a significant decrease in tardiness overall for students (Table 36). In addition, schools that had greater delays in school start times also tended to see the greatest decreases in tardiness.

Excused and Unexcused Absences

Comparisons of excused and unexcused absences were also conducted in schools and districts where possible. Analyses of absences categorized as excused and unexcused could only be carried out on data from two of the five school districts, Mahtomedi and Jackson Hole. For these two districts, the pre-post difference in excused absences was statistically significant for the across-grades comparisons, as well as for the sub-group comparison for 12th graders. Both outcomes were decreases. The pre-post difference in unexcused absences for Jackson Hole students was statistically significant and the direction of the difference indicated an increase in unexcused absences. Details regarding these results are provided in Appendices E and H.

GPA

Statistical comparisons were carried out on quarter, semester, or year GPAs, depending on the GPA data provided by the districts. Most districts were able to provide GPA data for core courses offered in 1st and 3rd periods, but not for overall GPAs. A core course was defined as a course in mathematics, science, social studies, or English. General results of the core course GPA analyses reveals statistically significant increases in GPA for all students in five of the six high schools/districts being examined.

Performance on Standardized Tests

It was not possible to compare pre-post standardized test performance in all subject areas due to changes in the tests that were administered or changes in the scoring scales. The subject area results summarized in Table 38 may be either for state-wide achievement tests or for the PLAN. No consistent patterns emerged in the analyses that were carried out. With respect to subject areas, three results were statistically significant; one result was an increase and two were decreases. Two of the five districts/schools saw a significant increase in their overall performance on national standardized achievement tests.

Vehicle Crashes During School Year Involving 16 to 18 Year Old Drivers

Minnesota

The vehicle crash data were provided by the Minnesota Department of Transportation's Office of Traffic, Safety and Technology. The data source for Minnesota is the Transportation Information System (TIS). We requested crash data for 16-18 year old drivers for the school year months of September through May for the school year before the start time delay and the school year after the start time delay. To ensure that the majority of drivers were enrolled in the schools of interest, we requested data for crashes occurring within the city limits of Cottage Grove, Woodbury, St. Louis Park, and Mahtomedi.

Thirteen codes were utilized for the physical condition of the driver. We selected three of these codes for our analyses: "Normal-No drugs or drinking," "Under the influence," and "Asleep." Thirty-five codes were used for contributing factors, 15 of which were related to driver behavior. We selected five of the driver behavior codes for our analyses: "Failure to yield right of way," "Over-correcting," "Driver inattention or distraction," "Driver inexperience," and "Driver on car phone, CB, or two-way radio." Because the code for "Driver on car phone, CB, or two-way radio" did not appear in any of the crash records, it was not included in the summary tables.

Wyoming

The vehicle crash data were provided by the Wyoming Department of Transportation. We requested crash data for 16-18 year old drivers for the school year months of September through May for the school year before the start time delay and the school year after the start time delay. To ensure that the majority of drivers were enrolled in the schools of interest, we requested data for crashes only occurring within Teton County.

Analysis categories utilized by Wyoming were modified to be as similar as possible to those utilized in the analyses of the Minnesota crash data. For example, if the reason for the accident indicated sleeping, the driver would have been categorized as "Asleep." However, no 16 to 18 year olds had this listed as reason for the accident. Drivers who were reported as running a red light or failing to yield the right of way were counted as failure to yield right of way. Drivers who were driving too fast for conditions were counted as driver inexperience. Drivers that were following too close were counted as driver inattention or distraction.

Discussion of Car Crash Results

In two of the four communities for which we had crash data and which had instituted a later start time for their high schools, the rate of car crashes for high school age drivers dropped by 65-70%. Another district saw a slight decrease of 6%, and the fourth experienced an increase of 9%. The district with the increase, St. Louis Park, is a first-ring suburb of Minneapolis. St. Louis Park contains many major highway routes

between the city of Minneapolis and other neighboring second- and third-ring suburbs. This may be a contributing factor in the increase in crash rates there, as those crashes may involve teens who attend local high schools in other nearby districts with earlier start times. The data that were provided did not enable us to identify which high schools the teens involved in crashes were attending.

Cottage Grove and Woodbury are communities that are considered second- or third-ring suburbs and are significantly distant from the central cities of Minneapolis and St. Paul. In addition, Cottage Grove and Woodbury are both experiencing high growth rates. They have combined into one school district called South Washington County. Their crash rate decreased by 6%. Mahtomedi is the other Minnesota school district, a second-ring suburb, and their crash rate dropped by 65%.

We believe that the crash data also need to be viewed within additional geographic lenses. For example, the geographic sizes of Cottage Grove and Woodbury, together as one school district, are 73 square miles in size, and are 6 to 12 times larger than either St. Louis Park (10.8 sq. mi) or Mahtomedi (5.5 sq. mi), and thus the driving distances are greater. Prior research has shown that the longer the distances for driving, the greater the problem with drowsy driving (Maclean et al., 2003).

The Teton County (Wyoming) School District had the latest school start time of the four districts involved in this portion of the research study and had a substantial reduction in car crashes during the school year after the later start time was initiated. The number dropped from 23 to 7 for drivers 16 to 18 years of age, which is a crash rate reduction of 70%. The fact that over 66% of Jackson Hole High School students now obtain more than 8 hours of sleep each school night may be the reason for the significant drop.

Finally, police officers on the scene of any crash make certain subjective assessments of contributing factors, the subjectivity of which makes an initial comparison of causal factors somewhat speculative.

However, the time of day is factual information, and it can be seen that crashes during the school year with the earlier start for the high school were three times more likely to happen in the time period between end of the school day and bedtime. After the later start time change, not only were there fewer crashes, but the proportion of crashes happening before school versus after school was about evenly split. Also, the factor of having greater driving distances for the Jackson Hole area, which is over 500 square miles, and which has the largest geographic size of all districts studied, makes the reduction of crashes by 70% all the more remarkable, given what was noted above about the link between drowsy driving and longer distances.

Finally, with Jackson Hole High School being the only major high school in Teton County, this allows for greater confidence that the drop in the crash rate is not influenced by other changes in other high schools nearby, since theirs is the only high school in the area.

Final Report Summary and Conclusions

Despite the strong medical evidence of the need for adolescents to obtain at least 8, and preferably 9, hours of sleep every night to maximize their neural development, a strong resistance to a delayed high school start time exists in many localities across the U.S. School districts are very complex organisms that link bureaucratic structures with community norms and family life patterns, and where homeostasis or maintenance of the status quo is probably the strongest force against adopting a later start time for high schools.

However, given the analyses summarized here, there are clear benefits for students whose high schools start at 8:30 AM or later. This would include, for teens who reported they got at least 8 hours of sleep per night, that they were more likely to say they have good overall health and were less likely to report being depressed or using caffeine and other substances (e.g., alcohol, tobacco, other drugs). Other positive findings include a significant reduction in local car crashes, less absenteeism, less tardiness, as well as higher test scores on national achievement tests. Most of the research completed prior to the study being reported here has been conducted in single districts, with none examining multiple school districts in multiple locations across the U.S., *using identical metrics* to assess changes. Replications of this study would go a long way in confirming what appear to be substantive findings.

Finally, conducting research in school districts has more challenges than anyone might imagine. Hurdles include such things as gaining access to the students for conducting a survey, administering student surveys prior to the start time delay so that pre-post analyses can be carried out, obtaining reliable comparative academic performance data, gaining IRB approval from the local school district to conduct the study, locating several districts who are willing to have their experiences thrust into public view, and so forth. Despite those hurdles, the findings of this research study reveal that there are empirically-based positive outcomes for adolescents whenever the start time of their high school is moved to a later time—with the starting time of 8:30 AM or later clearly showing the most positive results.