

School Start Times, Sleep, and Student Outcomes

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In the following report, Hanover Research examines the impact that school start times have on student achievement and other student outcomes. The report reviews literature on the effect of start times on academic achievement at the elementary, middle, and high school levels and introduces literature surrounding other student outcomes that may be impacted by changes to school start time. Hanover also provides additional information about the specific sleep needs and outcomes of sleep for elementary school-aged students.

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EXECUTIVE SUMMARY AND KEY FINDINGS

INTRODUCTION

The issue of school start times has received increased media attention as districts throughout the country consider delaying high school start times, often with the hope that students will receive more time to sleep in the mornings. In 2012, Montgomery County Public Schools (MCPS) convened a work group, The Bell Times Work Group, to examine the impact of adjusting school start times in the county. Through extensive research on adolescent sleep, the work group developed a series of schedule options for changing start times at all levels of schooling.

MCPS has tasked Hanover Research, a private research firm, to provide an exhaustive literature review on the association between school start times and student outcomes. This report serves as an independent review of the literature on school start times. The Bell Times Work Group published a report in October 2013 that included a literature review on the start times research since 1998. This external literature review examines many of the same peer-reviewed journal articles from the Bell Times Work Group Report due to the limited nature of the research base, with the addition of new research since the writing of the 2013 report.

This report examines student outcomes such as academic achievement and student well-being measures. In addition, MCPS requested a section on the unique sleep needs and sleep outcomes of elementary school-aged students. The literature base in this area is extremely limited, as most studies in this area focus on teens and adults. The report is divided into three sections:

- **Section I: School Start Time and Student Achievement** examines literature on school start times, comparing results of studies that suggest start times have positive, mixed, or no effect on student performance.
- **Section II: School Start Time and Other Student Outcomes** examines the research available on the effect that school start times may have on a variety of additional student outcomes, such as the amount of sleep, student mood, and car crash rates.
- **Section III: Sleep Needs of Elementary School Students** summarizes literature on the sleep needs of elementary school-aged students and investigates the relationship between sleep and various elementary student outcomes.

KEY FINDINGS

SCHOOL START TIMES AND ACHIEVEMENT OUTCOMES

- **The body of research on school start times does not provide conclusive evidence that start times impact student achievement.** The literature base demonstrates studies with various results (positive, mixed, and no effect) on academic measures that include standardized state test scores and grade point averages.

- **Studies that found a positive relationship between school start times and student achievement include students from elementary students up through college.** These studies also found that later start times were especially beneficial for low-performing students, and that start times even impacted performance in future subjects.
- **Other studies using data from Kansas, Minnesota, and Virginia found no such relationship between start times and achievement.** This result included a variety of student academic outcomes, such as grades, grade point average, and state assessments. Additionally, Hinrichs found no effect when looking for any differences in gender or poverty status.
- **Elementary school start times vary in their impact on student achievement.** One Kentucky study found early start times to negatively impact only elementary schools with lower levels of free/reduced lunch participants, while another study based in North Carolina found no effect on test scores.

SCHOOL START TIMES AND OTHER STUDENT OUTCOMES

- **Studies that examined start times on student sleep found that both middle and high school students slept more when their school start times were later.** Wahlstrom's 2002 study found that students went to sleep at the same time as before the change in start time, while Wolfson et al. found that students at the later starting high school went to sleep 22 minutes later.
- **As students received more sleep, feelings of sleepiness lessened while attention and feelings of alertness increased.** The extant literature states that even modest delays in start time improve measures of daytime sleepiness and fatigue. Some studies even reported improved behavior, reduced caffeine consumption, and better overall student moods following a delay in start time.
- **Start times were also found to improve rates of tardiness, although the impact on absences was mixed.** Some studies, such as Edwards, found absences declined when start times rose, while others, such as Hinrichs and Wahlstrom et al.'s 2014 study, found either no relationship or a mix of negative and positive results.
- **Teen car crash rates were found to greatly decrease when schools start later.** A study conducted by Danner and Phillips found that car crash rates were reduced in a Kentucky county after the high school implemented a delayed start time. An additional study by Vorona et al. compared the teen crash rate between two Virginia cities and found that the car crash rate among teens was significantly lower in the city with a later high school start time.

SLEEP NEEDS AND SLEEP OUTCOMES FOR ELEMENTARY SCHOOL-AGED STUDENTS

- **Elementary school students (ages 5 to 12 years) require 10 to 11 hours of sleep per night.** Student's habits and activities affect the amount and quality of sleep. For

example, increasing academic demands from school, sports and extracurricular commitments, and use of television, computers, and other devices can disrupt sleep and cause students to go to bed later.

- **Pre-adolescents are found to have early morning preferences, as compared to older children.** Although school-aged children begin to show signs of sleep phase preference (evening vs. morning type), researchers such as Carskadon found that younger children prefer earlier hours. The shift towards an evening preference usually occurs at adolescence when circadian patterns change.
- **The research on sleep outcomes for elementary school-aged children is very limited.** The majority of studies examine teens and adults, and much of the research that is available on young children occurs outside of the United States.
- **The limited studies that are available indicate that a lack of sleep has a negative impact on elementary-aged children.** The cognitive performance of young children is adversely affected by reductions in sleep, according to studies by Randazzo, et al. and Molfese. Additionally, long term physical health measures of children, such as obesity rates, were found to be associated with inadequate amounts of sleep.

SECTION I: SCHOOL START TIME AND STUDENT ACHIEVEMENT

A recent policy statement by the American Academy of Pediatrics has brought national attention to the issue of school start time. According to the policy statement, insufficient sleep and chronic sleep loss have become a public health epidemic among American adolescents, resulting in a host of academic, psychological, and health challenges. Some research suggests that later school start times might encourage healthier adolescent sleep patterns and lead to a variety of physical, mental, and social benefits.¹

While literature on school start time and adolescent sleep deprivation abounds, limited research highlights the relationship between school start time and student achievement. Few studies directly assess the impact of this association, instead focusing on the relationship between adolescent sleep patterns and student performance. In the following section, Hanover Research limits the scope of literature specifically to school start times and student achievement.

Our review of the extant literature yielded eight studies that examined the relationship between school start times and academic achievement at the elementary, middle, and high school levels. This report includes empirical studies that primarily focus on K-12 public education in the United States. In addition, Hanover categorizes the studies based on the statistical significance of the results. Hanover classifies the degree of each study's effect as "positive," "mixed," or "no" effect. Our classification of the studies' impact is as follows:

- **Positive effect:** Studies with positive effects found statistically significant results, indicating a positive relationship between school start time and student achievement outcomes.
- **Mixed effect:** Studies with mixed effects had statistically significant results that indicated both positive and negative effects of early school start time on student achievement outcomes.
- **No effect:** Studies with no effect did not find statistically significant results indicative of a relationship between school start time and student achievement.

The following figure presents the effect, student level, and achievement outcome measures used in the studies included in our review (see Figure 1.1).

¹ "School Start Times for Adolescents." American Academy of Pediatrics, 2014. p. 644, 646.
<http://pediatrics.aappublications.org/content/early/2014/08/19/peds.2014-1697.full.pdf+html>

Figure 1.1: Summary of School Start Times and Academic Achievement Literature

STUDY			LEVEL	ACADEMIC OUTCOME MEASURE	EFFECT
Author	Title	Year			
Carrell, et al. ²	A's from Zzzz's? The Causal Effect of School Start Time on the Academic Achievement of Adolescents	2010	College freshmen	Grades	Positive effect
Cortes, Bricker, and Rohlf's ³	The Role of Specific Subjects in Education Production Functions: Evidence from Morning Classes in Chicago Public High Schools	2012	High school	Grades, standardized test scores	Positive effect for math, no effect for English*
Edwards, F. ⁴	Early to rise? The effect of daily start times on academic performance	2012	Elementary, middle, and high school	Standardized test scores	Positive effect for middle and high school, no effect for elementary school*
Keller, et al. ⁵	Earlier School Start Times as a Risk Factor for Poor School Performance: An Examination of Public Elementary Schools in the Commonwealth of Kentucky	2014	Elementary school	Standardized test scores	Positive effect
Wahlstrom, et al. ⁶	Examining the Impact of Later High School Start Times on the Health and Academic Performance of High School Students: A Multi-Site Study	2014	High school	Grade point average, grades, standardized test scores	Mixed effect
Arlington Public Schools ⁷	Impact of 2001 Adjustments to High School and Middle School Start Times	2005	High school, middle school	Grades, grade point average	No effect

²Carrell, et al. "A's from Zzzz's? The Causal Effect of School Start Time on the Academic Achievement of Adolescents." University of California at Davis, October 5, 2010. <http://www.econ.ucdavis.edu/faculty/scarrell/sleep.pdf>

³Cortes, K., J. Bricker, and C. Rohlf's. "The Role of Specific Subjects in Education Production Functions: Evidence from Morning Classes in Chicago Public High Schools." *The B.E. Journal of Economic Analysis & Policy*, 12:1, 2012. <http://users.nber.org/~cortesk/bejeap2012.pdf>

⁴Edwards, F. "Early to rise? The effect of daily start times on academic performance." *Economics of Education Review*, 31, 2012. <http://teensneedsleep.files.wordpress.com/2011/04/edwards-early-to-rise-the-effect-of-daily-start-times-on-academic-performance-published-version.pdf>

⁵Keller, P., et al. "Earlier School Start Times as a Risk Factor for Poor School Performance: An Examination of Public Elementary Schools in the Commonwealth of Kentucky." *Journal of Educational Psychology*, June 16, 2014. <http://www.apa.org/pubs/journals/releases/edu-a0037195.pdf>

⁶Wahlstrom, et al. "Examining the Impact of Later High School Start Times on the Health and Academic Performance of High School Students: A Multi-Site Study." Center for Applied Research and Educational Improvement, February 2014. <http://conservancy.umn.edu/bitstream/11299/162769/1/Impact%20of%20Later%20Start%20Time%20Final%20Report.pdf>

⁷"Impact of 2001 Adjustments to High School and Middle School Start Times." Arlington Public Schools, June 2005. <http://www.fcps.edu/fts/taskforce07/documents/arlington605.pdf>

STUDY			LEVEL	ACADEMIC OUTCOME MEASURE	EFFECT
Author	Title	Year			
Hinrichs, P. ⁸	When the Bell Tolls: The Effects of School Starting Times on Academic Achievement	2011	High school	Standardized test scores	No effect
Wahlstrom, K. ⁹	Changing Times: Findings From the First Longitudinal Study of Later High School Start Times	2002	High school	Grades	No effect

* These studies are classified as “positive” because they indicate a statistically significant relationship between school start times and academic achievement in at least one academic subject or school level, with no negative findings.

SCHOOL START TIMES

The issue of optimal school start time has been debated at the national and local levels for over a decade. A national survey administered by the National Center for Education Statistics in 2001 found that nearly half of middle schools start at or before 8:00 a.m., with fewer than 25 percent starting after 8:30 a.m. As for high schools, a 2005 survey found that more than 50 percent of high schools started before 8:00 a.m. Notably, a recent study of high schools in New York City found that 10 percent of schools started at or before 7:30 a.m. and more than 80 percent of schools started at or before 8:30 a.m.¹⁰

Several national and local initiatives have developed in support of later high school start times. In 2009, Rep. Zoe Lofgren of California proposed House Concurrent Resolution 176, known as the “Zzz’s to A’s Resolution,” which resolved to delay high school start times to after 9:00 a.m.¹¹ Rep. Lofgren is currently finalizing a bill requiring the Department of Education to commission a study on school start times and student outcomes such as health and student achievement, in order to provide school districts with recommendations.¹² Similarly, a multitude of local initiatives have caused districts across the country to adopt later start times. Arlington Public Schools, for instance, adjusted the schedules of its high schools to start and end 45 minutes later during the 2001-2002 school year.¹³ Fairfax County

⁸Hinrichs, P. “When the Bell Tolls: The Effects of School Starting Times on Academic Achievement.” *Education Finance and Policy*, 6:4, Fall 2011.

<https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFjAA&url=https%3A%2F%2Fwww.aeaweb.org%2Faea%2F2011conference%2Fprogram%2Fretrieve.php%3Fpdfid%3D60&ei=hY0HVOqqC9WPNq2ugNAD&usg=AFQjCNF1E4L9oufa08F4UBKUpuiftkonjw&bvm=bv.74115972,d.eXY>

⁹Wahlstrom, K. “Changing Times: Findings From the First Longitudinal Study of Later High School Start Times.” *National Association of Secondary School Principals Bulletin*, 86:633, December 2002.
<http://teensneedsleep.files.wordpress.com/2011/04/wahlstrom-changing-times-findings-from-the-first-longitudinal-study-of-later-high-school-start-times.pdf>

¹⁰Jacob, B.A. and J.E. Rockoff. “Organizing Schools to Improve Student Achievement: Start Times, Grade Configurations, and Teacher Assignments.” The Hamilton Project at the Brookings Institution, September 2011. p. 6.

¹¹“House Concurrent Resolution 176.” U.S. Government Printing Office. <http://www.gpo.gov/fdsys/pkg/BILLS-111hconres176ih/pdf/BILLS-111hconres176ih.pdf>

¹²Emma, C. “Which States are Making the Grade? – Congress Could Pass More Education Bills This Year – ‘Davids v. New York’ Heads to Court.” Politico Morning Education, September 11, 2014.
http://www.politico.com/morningeducation/0914/morningeducation15258.html?ml=ae_1

¹³“Impact of 2001 Adjustments to High School and Middle School Start Times.” Op. cit., p. 1.

Public Schools in Fairfax County, Virginia is currently undertaking a similar review of its start times, considering four later start time options for its middle and high schools. The earliest option would delay high school start times to 8:00/8:10 a.m. with middle schools starting at 7:20 a.m., and the latest option would delay high school start times to 9:15 a.m. with middle schools starting at 8:20/8:30 a.m.¹⁴

According to a recent study by the Center for Applied Research and Educational Improvement at the University of Minnesota, more than 75 percent of high school students surveyed consider the ideal school start time to be 8:30 a.m. or later. More than 50 percent of students consider the ideal start time to be 9:00 a.m. or later. Figure 1.2 presents high school students' perceptions of ideal start times, based on a survey of high school students in Minnesota, Colorado, and Wyoming.

Figure 1.2: Students' Perceptions of Ideal Start Times

IDEAL START TIME	PERCENT OF RESPONDENTS
7:00 a.m.	3.2%
7:30 a.m.	5.1%
8:00 a.m.	16.3%
8:30 a.m.	24.8%
9:00 a.m.	35.8%
Later than 9:00 a.m.	14.8%

Source: Wahlstrom, et al.¹⁵

START TIMES AND STUDENT ACHIEVEMENT

Research on the relationship between school start times and student achievement is inconclusive, with different studies indicating positive, mixed, or no statistically significant result. We examine these studies in more depth below.

POSITIVE EFFECT

Several recent studies suggest that start time positively impacts academic performance. A 2012 study by economist Finley Edwards found that later start times improved the performance of middle school students on standardized tests in both reading and math.¹⁶ Using data from Wake County Public Schools in Wake County, North Carolina from 1999 to 2006, Edwards compared students grouped into two tiers: Tier I included students who attended middle schools that started between 7:30 a.m. to 7:45 a.m., and Tier II included students who attended middle schools that started between 8:00 a.m. to 8:45 a.m.¹⁷

¹⁴"Later Start Time Options." Fairfax County Public Schools. <http://www.fcps.edu/news/starttimes-options.shtml>

¹⁵Wahlstrom, et al., "Examining the Impact of Later School Start Times on the Health and Academic Performance of High School Students: A Multi-Site Study." Op. cit., p. 25.

¹⁶Edwards, F. "Early to rise? The effect of daily start times on academic performance." Op. cit., p. 970.

¹⁷Ibid., p. 974.

Edwards found that the effect of starting school one hour later was associated with an increase in standardized test scores by 1.8 percentile points in math and one percentile point in reading.¹⁸ Moreover, the benefits of later start times were pronounced for low-performing students: results indicated that effects were twice as large for students who scored in the bottom third of students than for those who scored in the top third of test-takers.¹⁹ Not only do the results of Edwards' study suggest that later start times benefit middle school students, he found that these results persisted into high school. When Edwards analyzed tenth grade comprehensive exams that measured growth in reading and math, he found that a one hour later start time in middle school was associated with a 2.0 and 1.6 percentile increase in high school math and reading, respectively.²⁰

Other empirical studies also found a relationship between start times and achievement for high school students. In a 2012 study of high schoolers from Chicago Public Schools, Cortes, Bricker, and Rohlfis evaluated the effects of first period classes on course grades and standardized test scores. They found that first period classes were associated with lower course grades and test scores.²¹ The effect of first-period courses was especially pronounced for certain student subgroups and academic subjects. The authors found that this effect "became greater as the amount of exposure increased over the course of the academic year for black students."²² Notably, math classes seem to impact other subject areas, in addition to having long term effects. Cortes and her colleagues found that first period math classes negatively affected reading test scores. Moreover, the study found that Algebra I courses were associated with lower grades in Algebra II in later years.²³ The authors recommend that "math classes for at-risk students should be scheduled after first period and that math teachers' preparation time should be scheduled during first period."²⁴

A 2010 study by Carrell, et al. on the impact of first period classes on the course grades of first-year students at the United States Air Force Academy (USAFA) provides perhaps "the strongest evidence" on the relationship between start times and academic outcomes.²⁵ The study found "a positive causal relationship between start time and academic performance for the students at USAFA," with earlier course times negatively affecting students' course grades.²⁶ Not only did these students perform worse in their first period classes, they performed worse in all of their courses.²⁷ The researchers found that the negative effects diminished as start times were moved later, from 7:00 a.m. to 7:50 a.m.²⁸

¹⁸ Edwards, F. "Early to Rise? The Effect of Daily Start Times on Academic Performance" Op. Cit.

¹⁹ Ibid.

²⁰ Ibid., p.982.

²¹ Cortes, K., J. Bricker, and C. Rohlfis., Op. Cit., p. 2.

²² Ibid., p. 22.

²³ Ibid., p. 30.

²⁴ Ibid., p. 32.

²⁵ Jacob, B. and J. Rockoff., Op. Cit., p.8.

²⁶ Carrell, et al., Op. cit., p. 13.

²⁷ Carrell, et al., Op Cit., p. 16

²⁸ Ibid., p. 12.

Although this study examined the behavior of high-achieving college students, Carrell et al. contend that their results are generalizable to high school students, as first semester college students are adolescents that have the same sleep patterns as high school-aged teens. Moreover, the authors suggest that their use of the USAFA sample, an elite group of high-achieving students with a preference for a regimented lifestyle, provides even stronger evidence for the adverse effects of early start times. If the elite USAFA students' performance was negatively impacted by early start times, it is likely that early start times would particularly affect the performance of average students.²⁹

MIXED EFFECT

A multi-site study conducted by Wahlstrom and her colleagues at the University of Minnesota found varying results when evaluating the effects of later high school start times on the academic performance of students in Minnesota, Colorado, and Wyoming.³⁰ Specifically, the study evaluated the academic performance of 9,000 high school students across eight high schools in five school districts after schools delayed start times.³¹ In their analysis of students' mean grade point average (GPA) of core subject area courses or grades by individual course,³² Wahlstrom et al. found that many of their sampled high schools saw increases in grades; however, Mahtomedi, Saint Louis Park, and South County experienced both increases and decreases in grades (see Figure 1.3).³³ Although the authors of the study concluded that "there are empirically-based positive outcomes for adolescents whenever the start time of their high school is moved to a later time,"³⁴ not all outcomes were shown to be positive. Wahlstrom and her colleagues found that an analysis of standardized achievement tests (based on state standardized test scores or the composite ACT or PLAN) followed "[n]o consistent patterns."³⁵ Results indicated most test scores had no significant differences, although the few subject areas that did show statistical significance varied in the direction of the relationship.³⁶

²⁹ Ibid., p. 2.

³⁰ Wahlstrom, et al., "Examining the Impact of Later School Start Times on the Health and Academic Performance of High School Students: A Multi-Site Study." Op. cit., pp. 8-10.

³¹ Ibid., p. 2. Note: data for the three participating South Washington County high schools were combined.

³² These authors examined total GPA of math, English, social studies, and science in 1st or 3rd period classes for all schools except for Mahtomedi and South Washington County high schools. For these schools, the authors were able to examine grades by course.

³³ Wahlstrom, et al., "Examining the Impact of Later School Start Times on the Health and Academic Performance of High School Students: A Multi-Site Study." Op. cit.

³⁴ Ibid., p. 52.

³⁵ Ibid., p. 41.

³⁶ Ibid., p. 41.

Figure 1.3: Change in Mean GPA for 1st or 3rd Period Core Courses After Delayed Start Time

GRADE LEVEL	HIGH SCHOOL/DISTRICT					
	FAIRVIEW	BOULDER	MAHOMETI	SAINT LOUIS PARK	SOUTH WASHINGTON COUNTY	JACKSON HOLE
All grades	Increase	Increase	Increase, Decrease	ns	Increase, Decrease	Increase
Grade 9	Increase	n/a	Increase, Decrease	n/a	n/a	Increase
Grade 10	ns	n/a	Increase, Decrease	n/a	Increase	Increase
Grade 11	Increase	n/a	Increase, Decrease	n/a	Increase	Increase
Grade 12	Increase	n/a	Increase, Decrease	n/a	Increase	Increase

Source: Wahlstrom et al.³⁷

Note: "Increase" indicates statistically significant increases in grade point average (GPA). "Increase, Decrease" indicates that the results were mixed: some GPAs increased, while others decreased. "n/a" means the analysis could not be completed. "ns" means that the results were statistically non-significant.

NO EFFECT

Despite the body of evidence that suggests that later school start times positively affect student achievement, a countervailing body of evidence suggests that start times have no impact on student achievement. In a study published in 2011, educational economist Peter Hinrichs evaluated the impact of high school start times on student achievement in two Minnesota districts, Minneapolis Public Schools (MPS) and St. Paul Public Schools. He compared the ACT test scores of students at St. Paul Public Schools, which started the school day at 7:30 a.m., to those of students in Minneapolis Public Schools, which adopted a later start time of 8:40 a.m. in 1997-1998.³⁸ He found no differences in ACT scores for districts that moved their start times later, compared to districts that kept the earlier start times.

Hinrichs also evaluated a broader sample of data from high schools in Kansas and Virginia to estimate the effects of start time on students' performance on standardized tests.³⁹ The analysis in Kansas was based on state testing data provided by the Kansas Department of Education. The use of these data avoided the selection bias that is present in using ACT scores. The results from Kansas supported his findings from Minnesota – he found no effect of school start time on test scores in reading, math, social studies, and science. He also found no effect when segmenting the data by gender or free/reduced lunch status. Hinrichs notes that he estimated a similar analysis on Virginia data, and these results corroborated the Kansas and Minnesota results.

³⁷Ibid., p. 40.

³⁸Hinrichs, P. Op. cit.

³⁹Ibid.

Arlington Public Schools (APS) examined a change to their high school start time to 8:15 a.m. in 2001. Concurrently, APS moved the middle school start time 20 minutes earlier than their previous start time, due to limited availability in buses and bus drivers.⁴⁰ APS found slight positive changes to grade point averages in the high school, and mixed results in the middle schools; however, these changes were “so slight that it did not represent a change in letter grades for the students.”⁴¹ In other words, the effect of school time changes made no significant impact on student grades.⁴²

Hinrichs proposes the following reasons why school start time may not impact students’ performance on standardized tests:⁴³

- While early start times may cause students to lose sleep and learn less per unit of time, they may learn more outside of school by being awake longer.
- Students may be able to adapt to early times by re-optimizing sleep patterns, such as catching up on sleep over the weekend.
- Students may adapt to early schedules with environmental and chemical stimulation, such as caffeine.
- Though students’ biological clocks may lead them to perform better later in the day, teachers may perform better earlier in the day, having a counteracting effect.
- Later start times could result in less time spent with parents in the morning, without affecting the amount of time spent with parents in the afternoon or evening.
- Before-school activities might nullify the effects of later start times.
- With later start times, students may miss instructional time in the afternoon due to early dismissal for athletic and extracurricular activities.

Nevertheless, Hinrichs’ findings of “no effect” corroborate research conducted by Wahlstrom in 2002. Wahlstrom evaluated data from Minneapolis Public Schools after the district changed the start time of seven high schools to 8:40 a.m.⁴⁴ Analyzing students’ letter grades in classes three years before and three years after the change, Wahlstrom identified an upward trend, but no statistically significant differences in students’ grades as a result of the later start time.⁴⁵ The study did not consider SAT and ACT test scores as a student achievement measure because students who take such exams tend to be academically gifted, resulting in overall higher scores.⁴⁶ Wahlstrom also highlighted the limitations of using grades as a measure of student achievement, as “grading is often a subjective action by teachers.”⁴⁷ While evidence indicated that start times do not influence academic outcomes,

⁴⁰ Arlington County Public Schools. Op. Cit., p. 1.

⁴¹ Arlington County Public Schools. Op Cit., p. 19.

⁴² Arlington County Public Schools. Op. cit., pp. 7-11.

⁴³ Bulleted points adapted from: Hinrichs, P. Op. cit., pp. 15-16.

⁴⁴ Wahlstrom, K. “Changing Times: Findings From the First Longitudinal Study of Later High School Start Times.” Op. cit., p. 4.

⁴⁵ Ibid., p. 11.

⁴⁶ Ibid., p. 12.

⁴⁷ Ibid., p. 11.

Wahlstrom’s results suggested that later start times have non-academic benefits, such as improving student attendance rates for students who were not continuously enrolled for two consecutive years in the same high school.⁴⁸ Such non-academic benefits could have “spillover” effects that lead to improvements in academic performance.

ELEMENTARY SCHOOL START TIMES AND ACHIEVEMENT

Although most literature on school start times focuses on adolescents, a small body of research suggests that school start times impact the academic performance of elementary school students. Keller et al. evaluated the effects of school start times on the test scores of elementary students on the Kentucky Performance Rating for Educational Progress (K-PREP) assessment.⁴⁹ Although schools that started earlier were associated with lower test scores, these results were only found in middle and upper class elementary schools.⁵⁰ While this finding was unexpected to the study’s authors, they attributed students’ poorer academic performance to the “physical, behavioral, and psychological ramifications of sleep deprivation.”⁵¹

In contrast to Keller et al.’s findings, in his study of the Wake County Public School System (described previously in this section), Edwards found that school start times had no effect on elementary student achievement. Specifically, Edwards examined the impact of start times on students’ math and reading test scores and found no relationship.⁵² However, Edwards cautions that since the sampled elementary schools started at 8:15 a.m. or 9:15 a.m., it is unclear whether the start times had no effect on elementary school-aged students or that elementary school start times were not early enough to show an impact in this analysis.⁵³

LIMITATIONS OF RESEARCH ON START TIMES AND ACHIEVEMENT

Several limitations exist in the literature of school start times and academic achievement that may skew or limit the generalizability of the results. First, the methodology used in studies on school start times limits the ability to provide causal evidence. Most studies are correlational in nature and are thus unable to provide empirical proof that changes in start times result in differences in student achievement.⁵⁴ According to Dr. Joseph Buckhalt, Director of the School Psychology Program at Auburn University, research using experimental designs would provide the best evidence of a relationship between start times and academic achievement, though such studies would be subject to multiple practical and technical difficulties.⁵⁵

⁴⁸Ibid., p. 8.

⁴⁹Keller, et al., Op. cit., p. 2.

⁵⁰Ibid., p. 6.

⁵¹Keller, et al., Op. cit., p. 6.

⁵²Edwards, F. “Early to rise? The effect of daily start times on academic performance.” Op. cit., p. 980.

⁵³Ibid., p. 981.

⁵⁴Carrell, et al., Op. cit., p. 2.

⁵⁵Buckhalt, J.A. “School Year Means Sleep Challenges for Kids of All Ages.” American Psychological Association, August 27, 2012. <http://www.apa.org/news/press/releases/2012/08/sleep-challenges.aspx>

Next, the variables used in start time studies can limit their impact. As Carrell et al. observe in their investigation of the effects of start times on students at the U.S. Air Force Academy, certain academic achievement measures may yield inaccurate or misleading results. For instance, the use of grades as a student achievement metric may be ineffective due to “heterogeneity of assignments and exams as well as the subjectivity of assigning grades to assessments across instructors.”⁵⁶ Similarly, the use of student scores on standardized tests such as the ACT is subject to selection bias, as students who register to take such exams tend to be high-performing, causing skewed results.⁵⁷ Other confounding factors, such as self-selection of schedules and the effects of instructors could influence the results of a school start time study.⁵⁸ Finally, as Keller et al. observe, research on school start times tend to focus on one school or district, making it difficult to estimate the widespread impact of start times on student achievement. Similarly, start time research often fails to address the differences in school and student characteristics. Keller et al. recommends future research to examine start times with consideration to socioeconomic and demographic characteristics.⁵⁹

⁵⁶Carrell, et al., Op. cit., p. 2.

⁵⁷Wahlstrom, K. “Changing Times: Findings From the First Longitudinal Study of Later High School Start Times.” Op. cit., p. 12.

⁵⁸Carrell, et al., Op. cit., p. 2.

⁵⁹Keller, et al., Op. cit., p. 2.

SECTION II: START TIME AND OTHER STUDENT OUTCOMES

In addition to academic outcomes due to school start times, studies have indicated numerous other non-academic outcomes that accompany changes to a school's starting time. This section of the report provides an overview of the research literature that examines the more expansive impact of changes to school start times, including student well-being measures.

The following figure presents an overview of the studies that are included in this section, including the title, year of publication, school level, and the effect of the specific outcome measures. As with the literature reviewed in Section I, we limit the scope of studies to research focused on K-12 public education in the United States. We use the same classification on the degree of each study's effect as "positive," "mixed," or "no" effect.

Figure 2.1: Summary of School Start Times and Other Student Outcomes Literature

STUDY			LEVEL	OTHER OUTCOME MEASURE	EFFECT
AUTHOR	TITLE	YEAR			
Arlington Public Schools ⁶⁰	Impact of 2001 Adjustments to High School and Middle School Start Times	2005	High school, middle school	School attendance, attentiveness, extracurriculars	No effect for attendance, positive effect for attentiveness, positive effect for extracurriculars
Boergers, et al. ⁶¹	Later School Start Time is Associated with Improved Sleep and Daytime Functioning in Adolescents	2013	High school	Sleep, mood, homework, athletics/extracurriculars	Positive effect for sleep, positive effect for mood, no effect for homework, no effect for athletics/extracurriculars
Danner, F. & B. Phillips ⁶²	Adolescent Sleep, School Start Times, and Teen Motor Vehicle Crashes	2008	High school, middle school	Sleep, teen car crash rates	Positive effect for sleep, positive effect for crash rates
Edwards, F. ⁶³	Early to Rise? The Effect of Daily Start Times on Academic Performance	2012	Elementary, middle, and high school	Attendance, time spent on homework, time spent watching television	Positive effect for attendance, positive effect for homework, positive effect for time watching television
Hinrichs, P. ⁶⁴	When the Bell Tolls: The Effects of School Starting Times on Academic Achievement	2011	High school	School attendance	No effect for attendance
Owens, J., et al. ⁶⁵	Impact of Delaying School Start Time on Adolescent Sleep, Mood, and Behavior	2010	High school	Sleep, mood and behavior	Positive effect for sleep, positive effect for mood and behavior

⁶⁰ "Impact of 2001 Adjustments to High School and Middle School Start Times." Arlington Public Schools, June 2005. <http://www.fcps.edu/fts/taskforce07/documents/arlington605.pdf>

⁶¹ Boergers, J., C. Gable, and J. Owens. "Later School Start Time is Associated with Improved Sleep and Daytime Functioning in Adolescents." *Journal of Developmental & Behavioral Pediatrics*. 2013. <http://www.gwern.net/docs/melatonin/2014-boergers.pdf>

⁶² Danner, F. and B. Phillips. "Adolescent Sleep, School Start Times, and Teen Motor Vehicle Crashes." National Center for Biotechnology Information. 2008. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2603528/#B14>

⁶³ Edwards, F. "Early to Rise? The Effect of Daily Start Times on Academic Performance." *Economics of Education Review*, 31, 2012. <http://teensneedsleep.files.wordpress.com/2011/04/edwards-early-to-rise-the-effect-of-daily-start-times-on-academic-performance-published-version.pdf>

⁶⁴ Hinrichs, P. "When the Bell Tolls: The Effects of School Starting Times on Academic Achievement." *Education Finance and Policy*, 6:4, Fall 2011. <https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB4QFJAA&url=https%3A%2F%2Fwww.aeaweb.org%2Ffaea%2F2011conference%2Fprogram%2Fretrieve.php%3Fpdfid%3D60&ei=hY0HVQqqC9WPNq2ugNAD&usg=AFQjCNF1E4L9oufa08F4UBKUpuiftkonjw&bvm=bv.74115972,d.eXY>

⁶⁵ Owens, J. et al. "Impact of Delaying School Start Time on Adolescent Sleep, Mood, and Behavior." *The Journal of the American Medical Association*. 2010. <http://archpedi.jamanetwork.com/article.aspx?articleid=383436>

STUDY			LEVEL	OTHER OUTCOME MEASURE	EFFECT
AUTHOR	TITLE	YEAR			
Vorona, R., et al. ⁶⁶	Dissimilar Teen Crash Rates in Two Neighboring Southeastern Virginia Cities with Different High School Start Times	2011	High school	Teen car crash rates	Positive effect for crash rates
Wahlstrom, K. ⁶⁷	Changing Times: Findings from the First Longitudinal Study of Later High School Start Times	2002	High school	Sleep, school attendance, attentiveness, mood and behavior, extracurriculars	Positive effect for sleep, mixed effect for attendance, positive effect for attentiveness, positive effect for mood and behavior, no effect for extracurriculars
Wahlstrom, K., et al. ⁶⁸	Examining the Impact of Later High School Start Times on the Health and Academic Performance of High School Students: A Multi-Site Study	2014	High school	Sleep, school attendance, tardiness, teen car crash rates	Positive effect for sleep, mixed effect for attendance, positive effect for tardiness, mixed effect for crash rates
Wolfson, A., et al. ⁶⁹	Middle School Start Times: The Importance of a Good Night's Sleep for Young Adolescents	2007	Middle school	Sleep, attendance, tardiness	Positive effect for sleep, no effect for attendance, positive effect for tardiness

⁶⁶ Vorona, R., M. Szklo-Coxe, A. Wu, M. Dubik, Y. Zhao, and J. Ware. "Dissimilar Teen Crash Rates in Two Neighboring Southeastern Virginia Cities with Different High School Start Times." National Center for Biotechnology Information. 2011. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3077341/>

⁶⁷ Wahlstrom, K. "Changing Times: Findings from the First Longitudinal Study of Later High School Start Times." *National Association of Secondary School Principals Bulletin*, 86:633, December 2002. <http://www.cehd.umn.edu/carei/publications/documents/Bulletin200212Wahlstrom.pdf>

⁶⁸ Wahlstrom, K. et al. "Examining the Impact of Later High School Start Times on the Health and Academic Performance of High School Students: A Multi-Site Study." Center for Applied Research and Educational Improvement, February 2014. <http://conservancy.umn.edu/bitstream/handle/11299/162769/Impact%20of%20Later%20Start%20Time%20Final%20Report.pdf?sequence=1&isAllowed=y>

⁶⁹ Wolfson, A., Spaulding, C. Dandrow, and E. Baroni. "Middle School Start Times: The Importance of a Good Night's Sleep for Young Adolescents." 2007. <http://www.ncbi.nlm.nih.gov/pubmed/17680731>

START TIMES AND SLEEP

The majority of the literature indicated that later school start times often resulted in more sleep for students.⁷⁰ Some studies suggested that students received more sleep because students' bed times remained the same after schools began later in the morning. Other studies found that bed times did shift, both earlier and later in the evening, but students still received more sleep than before a shift to a later start time.

A recent study conducted by Boergers, Gable, and Owens surveyed 197 students at a coeducational New England boarding school to determine the impact of a delay in school start time on Grade 9 through 12 students, and students at the post-graduate level. The researchers administered a survey to students in the fall semester when the school day began at 8:00 a.m. and surveyed the same students again in the winter semester after the start time was changed to 8:25 a.m. The survey asked the students about their sleep-wake behaviors, how well they functioned during the day, what activities they participated in, and other health related questions. The study found that students' bedtimes did not shift later after the start time change, and that students were receiving more sleep. In fact, the percentage of students receiving eight or more hours of sleep each night increased from 18 percent to 44 percent after the 25-minute delay. The authors also found that students who received less than eight hours of sleep in the fall (prior to the time change), and Grade 9 and 10 students were most likely to sleep longer after a start time delay. The findings also cited a significant decrease in the signs of daytime sleepiness, including falling asleep in class and tardiness. It is important to note that even after the delay, only 8.8 percent of students reported getting the recommended nine or more hours of sleep per night.⁷¹

A similar study conducted in 2010 by Owens et al. at a high school in Rhode Island involved 201 high school students in Grades 9 to 12. The research aimed to gauge the impact of a 30-minute delay in school start time on adolescents' sleep, mood, and behavior. The student participants were administered the Sleep Habits Survey before and after the change in school start from 8:00 a.m. to 8:30 a.m. After the time change, the average amount of sleep on a school night among students increased by 45 minutes, not only due to students waking up later in the day, but due to students heading to bed earlier. The authors found, through anecdotal comments, that the "perceived benefits of additional sleep motivated students to further modify their sleep-wake behaviors to optimize sleep duration."⁷² In addition, the percentage of students that were getting at least eight hours of sleep increased from 16.4 percent to 54.7 percent, and students also experienced more sleep satisfaction. The reports of sleep satisfaction were evidenced in the reduction of daytime sleepiness behavior like fatigue and tiredness. Similar to Boergers, Gable, and Owens, the authors of this study found that Grade 9 and 10 students received more sleep on school nights than upperclassman. This difference was almost 40 minutes between freshman and seniors in

⁷⁰ Wolfson, A., N. Spaulding, C. Dandrow, and E. Baroni. "Middle school start times: the importance of a good night's sleep for young adolescents." Op. cit.

⁷¹ Boergers, J., C. Gable, and J. Owens, Op cit., pp. 14-15.

⁷² Owens et al., Op. cit., p. 613.

this study. The study also found substantial variability between sleep patterns on the weekend compared to those during the week that was likely caused by students trying to compensate for their lack of sleep during the week.⁷³

Research on younger adolescents yielded similar findings. A 2007 study by Wolfson et al. focused on 205 middle school students in two urban, public middle schools in New England. One middle school (School E) started early at 7:15 a.m., while another school (School L) began at 8:37 a.m. (both schools began around 8:00 a.m. the year prior). Although students in the late-starting school reported waking up over an hour later than students in the early starting school, students in School L also went to sleep 22 minutes later.⁷⁴ This is contrary to Boergers et al. and Wahlstrom's 2002 study. In this study, Wahlstrom found that students continued to go to sleep at the same time after the start times shifted to later in the morning. This study found that students slept an additional hour longer than their early starting peers.⁷⁵

In their examination of high school students in Minnesota, Colorado, and Wyoming, Wahlstrom et al. (described in detail in Section I) found that the proportion of students receiving eight or more hours of sleep increased as school start times became later. Specifically, only 34 to 44 percent of students attending a school that started early (around 7:30 a.m.) received eight or more hours of sleep, compared to 57 to 66 percent of students that attended a school that started after 8:30 a.m. Interestingly, Wahlstrom and her colleagues also found that students who had a phone or computer in their bedrooms were more likely to get less than eight hours of sleep as compared to students who did not have these items in their rooms.⁷⁶

Research conducted by Danner and Phillips evaluated 9,966 students in Grades 6 to 12 within a large Kentucky county. The study began in Year 1 (1998) with a questionnaire that asked students specific questions about their sleep habits on school nights compared to non-school nights. The Year 1 survey respondents included approximately 66.9 percent of all middle and high school students enrolled in the county. The same survey was administered again one year later after the high school and middle school start times were changed from 7:30 to 8:30 a.m. and from 8:00 to 9:00 a.m., respectively. Through the analysis of responses to the questionnaires, Danner and Phillips found that the average hours of nightly sleep among adolescents increased while the amount of catch-up sleep on the weekends decreased.⁷⁷ The graphs in Figures 2.2 and Figures 2.3 illustrate the changes in sleep patterns after the hour change in start time.

⁷³ Ibid.

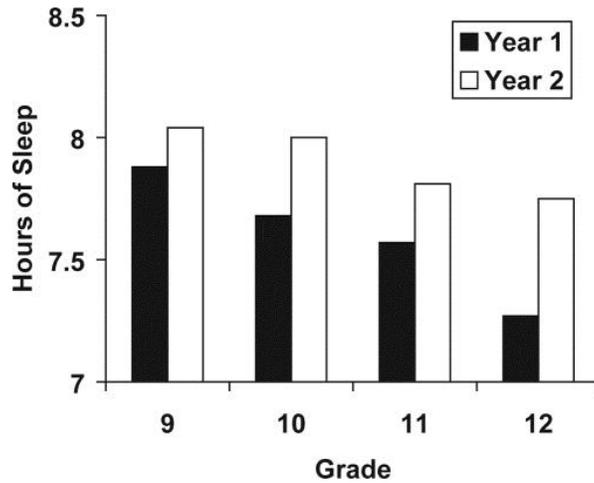
⁷⁴ Wolfson, A., N. Spaulding, C. Dandrow, and E. Baroni, Op. cit.

⁷⁵ Wahlstrom, K., "Changing Times: Findings from the First Longitudinal Study of Later High School Start Times," Op. Cit. p. 12

⁷⁶ Wahlstrom et al., "Examining the Impact of Later High School Start Times on the Health and Academic Performance of High School Students: A Multi-Site Study," Op. cit.

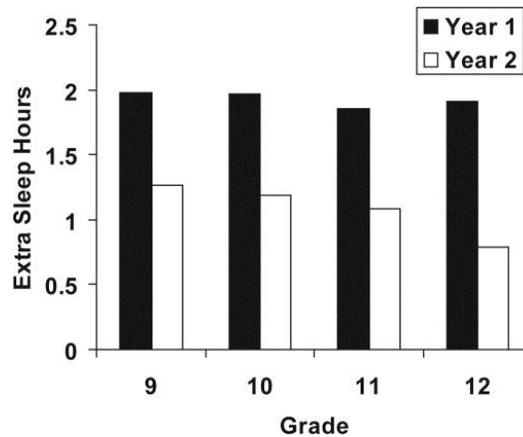
⁷⁷ Danner, F. and B. Phillips. "Adolescent Sleep, School Start Times, and Teen Motor Vehicle Crashes," Op. cit.

Figure 2.2: Changes in Hours of Sleep in Year 1 vs. Year 2



Source: Danner and Phillips⁷⁸

Figure 2.3: Changes in Catch-Up Sleep in Year 1 vs. Year 2



Source: Danner and Phillips⁷⁹

ATTENDANCE AND TARDINESS

Several studies have aimed to understand the impact that delayed start times have on school attendance and tardiness. In many instances, the researchers hypothesize that later start times will lead to an increase in attendance and a decrease in tardiness. The results of the existing research literature are somewhat mixed, however.

⁷⁸ Ibid.

⁷⁹ Ibid.

The 2002 Wahlstrom study on the Minneapolis Public School District highlighted in the previous section not only examined the impact of start times on achievement, but also student attendance rates. Wahlstrom evaluated attendance data for the two years prior to the start time change and for three years after the start time delay; the start times were 7:15 a.m. and 8:40 a.m., respectively. The attendance analysis included 50,962 high school students in Grades 9 to 12 from seven Minneapolis high schools.⁸⁰

Students in this study were divided into two subgroups based on their enrollment status. Those students that were continuously enrolled in the same high school for two or more years were in one group and students who made frequent moves into and out of multiple schools were categorized as discontinuous. The study did not find any significant changes in attendance rates after the start time delay for those students classified as continuously enrolled, but did find noteworthy differences in the average attendance rates for students that were discontinuously enrolled. The average attendance rates for discontinuously enrolled students in Grades 9 to 11 increased significantly after the later start time was implemented. The attendance changes for seniors in both groups varied and were not significantly different after the delayed start time. Wahlstrom hypothesized that this might be due to the fact that those students who remained in school until the Twelfth Grade were committed to finishing their degree regardless of the school start time, as they could have legally withdrawn from school at that age. When she examined attendance by ethnicity, she found that attendance rose for Asian, Hispanic, Black and White students in Grades 9 to 11. No differences were found among ethnic groups for students in Grade 12.⁸¹ The average attendance rates before and after the change for all grade levels and both groups are included in Figure 2.4.

Figure 2.4: Percentage of Average Attendance Rates

PERIOD	GRADE 9		GRADE 10		GRADE 11		GRADE 12	
	Cont.	Disc.	Cont.	Disc.	Cont.	Disc.	Cont.	Disc.
Pre-Start Time Change								
1995-1997	93%	72%	95%	76%	93%	72%	93%	88%
Post-Start Time Change								
1997-1999	94%	76%	95%	78%	94%	78%	91%	89%
1998-2000	94%	75%	94%	78%	94%	77%	89%	89%

Source: Wahlstrom⁸²

In the 2014 Wahlstrom et al. study, the researchers examined high school attendance rates along with a host of other student outcomes. These researchers found some statistically significant increases in rates of attendance when comparing students in the same grade level pre- and post-delay, although many of these results were non-significant. Interestingly, when comparing the same students from year to year, however, rates of attendance actually decreased. The authors had no explanation for this decrease and suggested the

⁸⁰ “Wahlstrom, K. “Changing Times: Findings From the First Longitudinal Study of Later High School Start Times.” Op. cit.

⁸¹ Ibid.

⁸² Ibid. p. 9.

need for additional research on this finding. Although attendance rates were inconsistent in the study, the majority of schools involved saw some reduction in tardiness overall, and the schools with the greatest time delays tended to have the largest decline in tardiness.⁸³

Wolfson et al. also examined attendance and tardiness in two middle schools in New England. Their study's results were consistent with Wahlstrom et al.'s 2014 study: Wolfson et al. found no differences in absences, but tardiness was almost four times as much in early starting schools than in the late starting schools.⁸⁴ Hinrichs' analysis on high schools in Minnesota also found no evidence of changes in attendance due to school start times.⁸⁵

Contrary to these findings, Edwards, in this study on middle schools in North Carolina, found that students who start school one hour later have 1.3 fewer absences during the school year. He suggests that the increase in absences may explain any differences in test scores.⁸⁶

Lastly, Arlington Public Schools found that regardless of start time, student attendance rates tended to decrease as students age. For all middle school and high school cohorts examined, the attendance rate of the students fell as grade level increased, even after the change in start times. Based on their findings, Arlington Public Schools reported that student maturity appears to have a larger impact on attendance rates than school start time.⁸⁷

ATTENTIVENESS, MOOD AND BEHAVIOR

There is a multitude of research that focuses on the impact of school starting times on cognitive performance in attention and concentration. Researchers have also examined the effect that sleep has on students' mood and behavior in school. The studies included below find that start times had a positive impact in these areas, due to the increased amount of sleep that students' received.

The Arlington Public Schools (APS) study measured the attentiveness of middle school and high school students before and after changes in school start time. Recall that while high schools started 45 minutes later, middle school students' start times were 20 minutes earlier than the previous start time. A survey was administered to participating students which asked them a series of questions on whether they were ready to start school, were alert during first period, were prepared for first period, and participated in class discussions during first period. A similar survey was also administered to teachers to gauge their perception of their students' attentiveness. Over 230 Eleventh Graders and 255 Eighth Grade students completed the student survey, while 232 high school and 179 middle school teachers completed the teacher survey.⁸⁸

⁸³ Wahlstrom et al., "Examining the Impact of Later High School Start Times on the Health and Academic Performance of High School Students: A Multi-Site Study," Op. cit.

⁸⁴ Wolfson, A., N. Spaulding, C. Dandrow, and E. Baroni, Op. cit.

⁸⁵ Hinrichs, P. "When the Bell Tolls: The Effects of School Starting Times on Academic Achievement." Op. cit. p. 11.

⁸⁶ Edwards, Op. cit.

⁸⁷ "Impact of 2001 Adjustments to High School and Middle School Start Times." Op. cit. p. 12-13.

⁸⁸ Ibid., p. 13-19.

APS found that the responses from high school students did not substantially change after the delay in start times, although the percentage of high school students that participated in class discussions “all of the time” increased from 31 percent to 42 percent. Middle school student results were skewed in the opposite direction. Whereas seven percent of middle school students felt ready to start school “none of the time” before the time change, when start times were moved to earlier in the morning, 19 percent of middle schoolers felt ready “none of the time.” The authors attribute these results as a possible “reflection of their dissatisfaction with the change in start times.”⁸⁹ See Figure 2.5.

Figure 2.5: Percent Student Response on Attentiveness

QUESTION	ALL OF THE TIME		SOME OF THE TIME		NONE OF THE TIME		NO RESPONSE	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
High School Students								
Ready to start school	20%	18%	52%	63%	22%	18%	7%	1%
Alert during first period	22%	20%	52%	64%	18%	16%	8%	1%
Prepared for first period	41%	47%	46%	49%	6%	4%	7%	1%
Participated in class discussions during first period	31%	42%	52%	47%	10%	9%	7%	1%
Middle School Students								
Ready to start school	35%	20%	51%	55%	7%	19%	7%	7%
Alert during first period	31%	14%	50%	63%	12%	17%	7%	6%
Prepared for first period	62%	53%	30%	40%	2%	2%	7%	5%
Participated in class discussions during first period	44%	35%	46%	55%	4%	5%	6%	6%

Source: Arlington Public Schools⁹⁰

Note: After the start time change, high schools started later while middle schools started earlier than previous years.

As for teacher perceptions (Figure 2.6), more high school teachers “strongly agreed” and “agreed” that their students’ were alert, prepared, and participated during first period after the later time change. The middle school teacher responses were less favorable, and mimicked the student responses. Middle school teachers reported that students were neither as alert nor prepared after school started earlier in the day. Teachers also noticed a decline in class participation.⁹¹

⁸⁹ Ibid., p. 15

⁹⁰ Ibid., pp. 15-16

⁹¹ Ibid., pp. 16-18.

Figure 2.6: Percent Teacher Response on Student Attentiveness

QUESTION	STRONGLY AGREE		AGREE		DISAGREE		STRONGLY DISAGREE		NO OPINION		NO RESPONSE	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
High School Teachers												
Alert during first period	1%	12%	25%	41%	38%	17%	9%	11%	22%	24%	6%	5%
Prepared for first period	3%	10%	34%	41%	28%	20%	6%	8%	23%	16%	6%	6%
Participated in class discussions during first period	3%	13%	43%	47%	17%	14%	5%	4%	24%	15%	7%	7%
Middle School Teachers												
Alert during first period	10%	11%	50%	35%	11%	17%	3%	18%	25%	16%	1%	3%
Prepared for first period	8%	5%	55%	46%	10%	31%	1%	8%	26%	18%	1%	1%
Participated in class discussions during first period	10%	10%	58%	50%	7%	16%	0%	7%	24%	17%	2%	1%

Source: Arlington Public Schools⁹²

Note: After the start time change, high schools started later while middle schools started earlier than previous years.

The 2002 Wahlstrom et al. study conducted a survey with teachers to evaluate the changes in students that staff members noticed after the start time delay was implemented. More than half of teachers reported more students being alert during the first two periods of the school day than when school started earlier. These authors also found that the majority of high school principals indicated (through interviews) that they observed a change in the mood of students overall. Generally, the principals reported that the hallways during passing periods and the cafeteria during lunch were calmer than before the change. Five out of eight principals stated that they were dealing with less disciplinary referrals as well. The school counselors and nurses that were interviewed also conveyed similar feelings about students' calmer dispositions. Moreover, the counselors reported that fewer students were coming to them about relationship problems with their peers and/or parents. Urban and suburban parents were interviewed about the start time change as well, and although there were complaints surrounding the inconvenience that the start time posed for scheduling and transportation, the majority of parents claimed that their high school children were "easier to live with."⁹³

⁹² Ibid.

⁹³ Wahlstrom, K. "Changing Times: Findings from the First Longitudinal Study of Later High School Times." Op. cit. pp. 16-18.

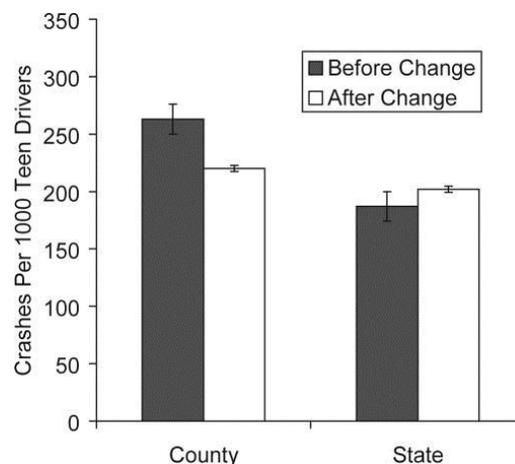
Boergers et al. also examined changes in students' mood before and after a 25-minute delay in start time in a coeducational boarding school. Boergers et al. found that before and after the delay, inadequate sleep was associated with greater levels of depression, sleepiness, and caffeine consumption; however, after the change in start time, the student outcomes in each of these areas improved significantly as more students reported longer durations of sleep.⁹⁴

START TIMES AND CAR ACCIDENTS

In addition to individual student outcomes, researchers have investigated the impact of school starting times on car crash rates in their communities. The majority of studies find a decrease in car accidents when schools start later in the day, however one district in Minneapolis saw a small increase in teen car crashes.

Danner and Phillips' study of one school district in Kentucky examined rates of motor vehicle crashes among 17 and 18 year olds before and after the high school start time change. Crash rates were computed for both the county and the entire state of Kentucky (excluding the county's data) and were calculated for the two years before the school district changed its start time and for the two years after the change. The rates of crashes in the county decreased following the change in school start time, even with rapid population growth in the area. Specifically, the county's crash rates decreased 16.5 percent, whereas other areas of the state increased 7.8 percent in crashes during the same time period.⁹⁵ Figure 2.7 compares the state and county crash rates before and after the start time change.

Figure 2.7: State and County Crash Rates in Year 1 vs. Year 2



Source: Danner and Phillips⁹⁶

⁹⁴ Boergers, J., C. Gable, and J. Owens. "Later School Start Time Associated with Improved Sleep and Daytime Functioning." Op. cit. p. 15.

⁹⁵ Danner, F. and B. Phillips. "Adolescent Sleep, School Start Times, and Teen Motor Vehicle Crashes." Op. cit.

⁹⁶ Ibid.

A similar study was conducted in Virginia where researchers compared the teen crash rates of Virginia Beach and Chesapeake, two similar and neighboring cities with different high school start times. Virginia Beach high schools started 75-80 minutes earlier than the high schools in Chesapeake. The study compared the crash data for 16 to 18 year old drivers in 2007 and 2008 across the two cities, and found that Virginia Beach had higher teen car crash rates. While all drivers (excluding 16 to 18 year olds) in Virginia Beach generally had higher rates of car crashes than Chesapeake drivers, the difference was far more pronounced for teen drivers. In fact, Vorona et al. found that the difference in teen crashes between the two cities were 4.5 times higher than the crash rate difference for all other ages.⁹⁷

Finally, Wahlstrom et al.'s 2014 study included teen car crash data for 16 to 18 year old drivers in three areas in Minnesota, and in Teton County, Wyoming. These authors found that in three of four communities, car crash rates dropped when high schools instituted later start times. The rate of car accidents dropped by as much as 70 percent in one district. The fourth district saw a small increase of 9 percent in their crash rates, which the authors suspect is due to crashes involving "teens who attend local high schools in other nearby districts with earlier start times."⁹⁸

TIME ON HOMEWORK, ATHLETICS, AND EXTRACURRICULARS

A common critique of later start times and subsequently later release times is that it leaves less time for students to do their homework and participate in afterschool activities. Generally, the literature finds no negative impact on participation in extracurricular activities and athletics afterschool due to a delay in school start times. One study also finds that later start times are associated with more time spent on homework and less time watching TV.

Boergers et al., cited previously in this section, found that later school start times did not have an effect on the amount of time students spent working on their homework. There were also "no significant difference in hours spent on...school sports, organized community sports, music activities, volunteer work, or hanging out with friends."⁹⁹ These researchers also found no change in tiredness during sports or social activities.¹⁰⁰

Based on teacher focus groups and interviews in Wahlstrom's 2002 study, teachers reported that districts that started later in the morning had shortened practices, extended-day

⁹⁷ Vorona, R., M. Szklo-Coxe, A. Wu, M. Dubik, Y. Zhao, and J. Ware. "Dissimilar teen crash rates in two neighboring southeastern Virginia cities with different high school start times." Op. cit.

⁹⁸ Wahlstrom, K. "Examining the Impact of Later High School Start Times on the Health and Academic Performance of High School Students: A Multi-Site Study." Op. cit., p. 48.

⁹⁹ Boergers et al., Op. cit. p. 15.

¹⁰⁰ Ibid.

programs, and rehearsals in the afternoons. These teachers did note that levels of participation in afterschool activities did not change due to school start times, however.¹⁰¹

APS's start time study found that students participated in after school activities at the same level or more after the change in start times for both middle and high schools. More specifically, 65 percent of high schoolers "indicated that either there was no difference in their participation or that they were participating more in 2001-02."¹⁰² Likewise, 24 percent of middle schoolers reported no difference in their participation and 42 percent were participating more. The authors suggest that the earlier start time in the middle school allowed for additional programming and/or after school activities coordinators.¹⁰³

Finally, the 2012 Edwards study (described in detail in Section I) also examined self-reported data from students about how much time they spent each day doing homework and watching television. He found that students who started school one hour later watched 12 minutes less of television each day and spent nine minutes more on homework each week. Edwards hypothesized that this was the case because students who started school earlier came home earlier and may spend more time alone watching television (and not being supervised on homework) before their parents arrive home.¹⁰⁴

¹⁰¹ "Wahlstrom, K. "Changing Times: Findings From the First Longitudinal Study of Later High School Start Times." Op. cit.

¹⁰² "Wahlstrom, K. "Changing Times: Findings From the First Longitudinal Study of Later High School Start Times." Op. cit., p. 23

¹⁰³ Ibid.

¹⁰⁴ Edwards, F. "Early to rise? The effect of daily start times on academic performance." Op. cit. p. 982.

SECTION III: SLEEP NEEDS AND SLEEP OUTCOMES OF ELEMENTARY SCHOOL-AGED STUDENTS

It is common knowledge among parents of elementary school-aged students that sleep is important to their children's health. However, the amount and quality of sleep required by children at each age and stage of development is not often clearly understood. In this section, Hanover Research examines literature on the science of sleep, and the sleep needs of elementary school-aged students.

THE SCIENCE OF SLEEP

To understand the majority of research surrounding the sleep patterns of young children, it is necessary to have a basic understanding of the science of sleep. The sleep cycle is comprised of two phases that range from light sleep to deep sleep. The two main phases are Rapid Eye Movement Sleep (REM) and Non-REM Sleep (NREM).¹⁰⁵

- **REM Sleep:** This phase of sleep involves extensive brain activity but during this phase of sleep the body suppresses muscle activity. This is the point of sleep in which dreaming occurs.¹⁰⁶
- **NREM Sleep:** This level of sleep has four stages within that range, from light sleep to the deepest sleep possible, that is also referred to as Slow-Wave Sleep (SWS).¹⁰⁷
 - Stage 1: A period of light sleep that bridges being awake and being asleep
 - Stage 2: The period where light sleep transitions into deeper sleep. This stage is marked by changes in brain-wave patterns.
 - Stage 3-4: The periods of deepest sleep that comprises about 12 to 15 percent of total sleep time.¹⁰⁸ The amount of time spent in SWS sleep varies depending on how long a person has been awake prior to sleeping. Children usually experience large amounts of Stage 3-4 sleep that progressively decreases as they get older.¹⁰⁹

Aging has an impact on the amount of sleep required and the way a person regulates their sleep. Infants require the most sleep and usually average about 16 hours a day while the adult averages approximately eight hours per night.¹¹⁰ Although sleep habits change slightly

¹⁰⁵ "Sleep." Encyclopedia of Children's Health. <http://www.healthofchildren.com/S/Sleep.html>

¹⁰⁶ Ibid.

¹⁰⁷ Ibid.

¹⁰⁸ Ibid.

¹⁰⁹ Dahl, R. and D. Lewin. "Pathways to Adolescent Health: Sleep Regulation and Behavior." *Journal of Adolescent Health*. 2002. p. 177. <http://www.sciencedirect.com/science/article/pii/S1054139X02005062#>

¹¹⁰ Ibid. p. 177.

as a person ages, there are four areas of sleep needs that are systematically altered during the transition from childhood into adolescence:

- There is a decrease in the duration of REM and Stage 3-4 sleep
- A more adult-like pattern of REM sleep develops
- There is an increase in daytime sleepiness
- There is a shift in the circadian pattern toward a preference for later bedtimes and wake-up times

Though all these changes are important, the shift in the circadian pattern is most notable in regards to school start times. The circadian timing system is the function of sleep that regulates the timing associated with waking and sleeping during a daily cycle.¹¹¹ For younger children, parents often play an integral role in the child's development of appropriate time cues for a sleep-wake cycle through enforced bedtimes. The majority of children under the age of 10 will sleep for approximately ten hours before they wake up naturally on a school day or a weekend.¹¹² During puberty notable biological circadian changes occur and adolescents shift toward a preference for delayed circadian patterns, meaning teens naturally prefer to stay up later and sleep in later.¹¹³ This occurrence is coupled with the fact that teens often set their own bed times and have access to a variety of stimulating night-time activities including videogames, television, and internet.¹¹⁴

CIRCADIAN RHYTHMS FOR YOUNG CHILDREN

The majority of research revolving around circadian rhythms focuses on very young children (infants and toddlers), children with sleeping disabilities, or concentrates on the shift that occurs at adolescence; therefore information about circadian rhythms in healthy elementary aged children is extremely limited.

One of Carskadon's first studies on the circadian timing in young children was a survey of 275 Sixth Grade girls on their physical development and circadian phase preference (i.e., their preference for mornings or evenings). The study found a significant relationship between the girls' physical development and their circadian patterns – the more mature girls favored later hours while the less mature girls favored earlier hours.¹¹⁵

¹¹¹ Carskadon, M. "Sleep and Circadian Rhythms in Children and Adolescents: Relevance for Athletic Performance of Young People." *Clinics in Sports Medicine*. 2005. p. 319. <http://www.ncbi.nlm.nih.gov/pubmed/15892926>

¹¹² *Ibid.*, p. 320.

¹¹³ "Pathways to Adolescent Health: Sleep Regulation and Behavior." *Op. cit.* p. 179

¹¹⁴ Carskadon, M., "Sleep and Circadian Rhythms in Children and Adolescents: Relevance for Athletic Performance of Young People." *Op. Cit.* p. 320.

¹¹⁵ Carskadon, M., C. Vieira, and C. Acebo. "Association Between Puberty and Delayed Phase Preference." *Sleep*, 16, 1993, pp. 258-62, as cited from Carskadon, M. "When Worlds Collide: Adolescent Need for Sleep Versus Societal Demands." Phi Delta Kappa International, Inc. 1999. p. 3. https://www.spps.org/uploads/when_worlds_collide-carskadon.pdf

According to Jenni and Carskadon, the shift in circadian sleep phase preference begins to occur in children sometime between ages 6 to 12, thus it is not possible to determine the ideal bedtime for all children at a specific age since the biological changes occur so variably. It is important to note that the elementary years comprise a formative period wherein problematic sleep habits tend to develop in children.¹¹⁶

SLEEP DURATION AND PATTERNS FOR YOUNG CHILDREN

According to research presented by the National Sleep Foundation, sleep needs vary among individuals, as some people require more sleep than others.¹¹⁷ However, sufficient sleep is essential to the healthy development of young children, especially between 5 and 12 years of age, when children experience rapid development. The sleep needs of elementary school-aged students change as children develop.¹¹⁸ While preschool-aged students (ages 3 to 5 years) require 11 to 13 hours of sleep each night, elementary school-aged children (ages 5 to 12 years) require 10 to 11 hours of sleep.¹¹⁹

In addition to sleep duration, children's sleep patterns change as they develop. While young children typically require daytime naps as well as a long nighttime session, sleep typically becomes consolidated into a single nighttime session when children reach ages 6 or 7.¹²⁰

While preschool-aged students require 11 to 13 hours of sleep each night, elementary school-aged children require 10 to 11 hours of sleep.

School-aged children's sleep is characterized by 50-minute cycles of deep, slow-wave sleep. During slow-wave sleep, brain activity declines and it becomes increasingly difficult to awaken.¹²¹ Research suggests that slow-wave sleep contributes to children's learning and memory.¹²² However, the number of slow-wave sleep periods decline as children enter the early stages of adulthood.¹²³

Other habits and activities may impact the amount and quality of sleep that elementary school students receive each night. Increasing academic demands from school, as well as sports and extracurricular commitments, may delay children's sleep time. In addition, the

¹¹⁶ Jenni, O. and M. Carskadon. "Normal Human Sleep at Different Ages: Infants to Adolescents." Sleep Research Society. p. 14. <http://www.scifun.org/conversations/Conversations4Teachers/Chapter%201.pdf>

¹¹⁷ "How Much Sleep Do We Really Need?" National Sleep Foundation. <http://sleepfoundation.org/how-sleep-works/how-much-sleep-do-we-really-need>

¹¹⁸ Amschler, D.H. and J.F. McKenzie. Elementary Students' Sleep Habits and Teacher Observations of Sleep-Related Problems." The Journal of School Health, 75:2, February 2005. p. 50.

¹¹⁹ "Children and Sleep." National Sleep Foundation. <http://sleepfoundation.org/sleep-topics/children-and-sleep/page/0%2C2/>

¹²⁰ "Changes in Sleep with Age." Division of Sleep Medicine at Harvard Medical School. <http://healthysleep.med.harvard.edu/healthy/science/variations/changes-in-sleep-with-age>

¹²¹ "Natural Patterns of Sleep." Division of Sleep Medicine at Harvard Medical School.

<http://healthysleep.med.harvard.edu/healthy/science/what/sleep-patterns-rem-nrem>

¹²² Buckhalt, J.A. "School Year Means Sleep Challenges for Kids of All Ages." American Psychological Association, August 27, 2012. <http://www.apa.org/news/press/releases/2012/08/sleep-challenges.aspx>

¹²³ "Changes in Sleep with Age." Op. cit.

use of television, computers, and other devices can disrupt sleep and cause students to go to bed later. According to the National Sleep Foundation, watching TV at night is associated with “bedtime resistance, difficulty falling asleep, anxiety around sleep, and sleeping fewer hours.”¹²⁴ To ensure children receive sufficient and quality rest, the National Sleep Foundation recommends the following practices:¹²⁵

- Teach school-aged children about healthy sleep habits.
- Continue to emphasize need for regular and consistent sleep schedule and bedtime routine.
- Make child's bedroom conducive to sleep – dark, cool and quiet.
- Keep TV and computers out of the bedroom.
- Avoid caffeine.

SLEEP OUTCOMES FOR YOUNG CHILDREN

Though much of the research surrounding sleep needs is focused on infants and adolescents, the problems associated with lack of sleep are not limited to these groups. Approximately 11 to 12 percent of elementary school children experience daytime sleepiness and 18 to 21 percent report daytime fatigue.¹²⁶ A number of researchers have also maintained that sleep plays an important role in brain development and learning during childhood:

The influence of problem sleepiness on children is multidimensional and may include decreased cognitive functioning and academic performance, increased aggression, and other behavioral problems, and increase vulnerability to accidents.¹²⁷

A 2004 study conducted by James Spilsbury examined the sleep habits of 755 school children between the ages of 8 to 11 living in urban areas of Cleveland, Ohio. The study required the children to complete a seven-day sleep journal and their guardian also had to complete a questionnaire about the child’s sleep and health. The study concluded that overall, a large portion of elementary school-aged children sleep less than the recommended nine hours per night. However, the *mean* sleep duration for all children was 9.63 hours and the analysis showed a statistically significant decrease in mean sleep duration as children got older. Minority boys reported the least amount of sleep time; in fact, the shortest mean sleep duration was reported among older minority boys (9.28 hours, see Figure 3.1). In addition, 43 percent of 10 to 11 year-old boys reported less than nine hours of sleep per night. The study also examined bedtimes and found that minority

¹²⁴“Children and Sleep.” National Sleep Foundation. <http://sleepfoundation.org/sleep-topics/children-and-sleep/page/0%2C3/>

¹²⁵Bulleted points taken verbatim from: “Children and Sleep.” Op. cit.

¹²⁶Spilsbury, et al. “Sleep Behavior in an Urban US Sample of School-aged Children.” *The Journal of the American Medical Association Pediatrics*. 2004. <http://archpedi.jamanetwork.com/article.aspx?articleid=485834>

¹²⁷Ibid.

children were more likely than nonminority children to have a bedtime of 11 p.m. or later.¹²⁸

Figure 3.1: Adjusted Mean Length of Sleep

ETHNICITY AND GENDER	8.5 YEARS OLD	9.5 YEARS OLD	10.5 YEARS OLD
Nonminority girls	9.85	9.69	9.55
Nonminority boys	9.82	9.67	9.52
Minority girls	9.83	9.68	9.53
Minority boys	9.58	9.43	9.28

Source: Spilsbury¹²⁹

COGNITIVE DEVELOPMENT

In order to be successful in school settings, children must be able to listen to a teacher's instructions, apply what they are taught, and retain new concepts; therefore cognitive abilities are particularly important to student achievement. There has been vast research about the cognitive effects of reduced sleep on adults, but the research on elementary-aged children is somewhat limited due to the ethical concerns associated with depriving young children of sleep.¹³⁰ The studies that do exist find that children's cognitive performance is at least somewhat impacted by their amount of sleep.

Randazzo and her peers conducted a study in 1998 to test the cognitive functioning of children following acute sleep restriction. The research included 16 children between the ages of 10 and 14 years old and took place over the course of one day. The children were randomly assigned to a control group or a sleep restriction group (treatment group), for one night while in a sleep laboratory. Those children in the control group were given 11 hours in bed while the children in the sleep restriction group were given only five hours in bed. The following day, both groups were evaluated on their cognitive performance and sleepiness measures during four sessions throughout the day that occurred every two hours. The authors concluded that executive function skills, such as skills that "enable the individual to engage in creative, adaptive learning by initiating and regulating retrieval of knowledge from long-term memory, modifying the knowledge base, and mediating problem-solving" may be impaired by sleep loss.¹³¹ Notably, measures of rote performance and less-complex forms of cognitive functioning, like memorization, were similar across both groups. The authors suggest that the nature of routine/rote tasks (i.e., low cognitive load) account for the lack of differences between the two groups.¹³²

¹²⁸ Ibid.

¹²⁹ Ibid., p. 991

¹³⁰ Buckhalt, J. "Sleep Loss Affects Children's Ability to Process Speech." *Psychology Today*. 2013. <http://www.psychologytoday.com/blog/child-sleep-zzzs/201303/sleep-loss-affects-children-s-ability-process-speech>

¹³¹ Randazzo, AC, et al. "Cognitive function following acute sleep restriction in children ages 10-14." *National Center for Biotechnology Information*. 1998. p. 866. <http://www.ncbi.nlm.nih.gov/pubmed/9871948>

¹³² Ibid.

A comparable study led by Dennis Molfese also studied the effects of sleep on six children from ages 6 to 8. The researchers asked the parents of these children to record the sleeping patterns of their children for one week.¹³³ After the normal sleeping patterns were recorded, the researchers assigned some students to the experimental group and assigned the rest to a control group. The children in the experimental group were allowed to sleep for one hour less every night for a week while the control group remained on their normal sleeping schedule. After a week of mild sleep restriction for the experimental group, the children were given a series of tasks designed to measure their attention, speech perception, and executive function. Those students in the experimental group showed slower responses. Overall, the Molfese study demonstrated that even small amounts of sleep deprivation can have a negative impact on children's cognitive functioning.¹³⁴

HEALTH

The health of young children is also associated with the amount of sleep they receive. Some studies find an increase in depression and violence in the home, while others find a relationship between obesity and sleep.

A 2007 study conducted by researchers at the Columbia School of Nursing sought to examine the characteristics associated with inadequate sleep in children. The study examined a nationally representative sample of 68,418 children between the ages of 6 and 17 years old. The researchers then divided the children into two subpopulations based on their age range, from age 6 to 11, and 12 to 17. The data utilized in this study came from parent interview responses about children's sleep habits and other characteristics. The related health characteristics of school-aged children (6 to 11 years) with or without adequate sleep as reported by parents are included in Figure 3.2. Inadequate sleep indicated that the child did not sleep well at least one night the week prior to the survey.¹³⁵

The authors found the following factors to be associated with children with inadequate sleep in both age groups:¹³⁶

- Presence of one or more depressive symptoms,
- Less frequent days of physical activity,
- Living in a home where parents argue heatedly or shout,
- On rare occasions respond by hitting or throwing things during family disagreements, or

¹³³ Molfese, D., et al. "A One-Hour Sleep Restriction Impacts Brain Processing in Young Children Across Tasks: Evidence From Event-Related Potentials." *Developmental Neuropsychology*. 2013. <http://www.tandfonline.com/doi/full/10.1080/87565641.2013.799169#tabModule>

¹³⁴ Buckhalt, J. "Sleep Loss Affects Children's Ability to Process Speech." *Op cit*.

¹³⁵ Smaldone, A. et al. "Sleepless in America: Inadequate Sleep and Relationships to Health and Well-being of Our Nation's Children." *American Academy of Pediatrics*. 2006. http://pediatrics.aappublications.org/content/119/Supplement_1/S29.full.pdf+html

¹³⁶ Quoted with minor changes from: *Ibid.*, p. S31

- Perceive that the environment at home, school, or in the community is not always safe.

Specifically for elementary-aged children, inadequate sleep was associated with having problems at school, and fair or poor paternal general health.¹³⁷

Figure 3.2: Characteristics of Children With or Without Adequate Sleep

VARIABLE	INADEQUATE SLEEP	ADEQUATE SLEEP
Health Status		
Excellent	57.3	62.1
Very good, good	38.4	34.9
Fair, poor	4.3	3.0
Comorbid conditions		
Depression/anxiety	5.3	2.9
Behavioral conduct problem	8.7	5.3
Developmental delay or physical impairment	3.7	3.8
Atopic conduction	32.4	29.1
Frequent or severe headache	5.9	4.4
Learning disability	11.2	9.3
ADD/ADHD	9.6	7.1
Depressive symptoms		
Never	11.4	19.7
Sometimes	73.0	69.8
Always, usually	15.6	10.5
Physical Health		
Overweight	27.5	28.3

Source: Smaldone et al.¹³⁸

A 2007 study examined the potential link between shorter sleep duration and childhood weight problems. The study analyzed the sleep duration and BMI data of 785 children in the third and sixth grade. The sleep duration was reported by parents and the height and weight of children were measured. The study defined “overweight” as a BMI greater than or equal to the 95th percentile for age and gender; 18 percent of the children included in this study were overweight in the sixth grade. Through logistic regression modeling, the study found that shorter sleep duration in Grade 6 was independently associated with a greater likelihood of being overweight. In addition, shorter sleep duration in Grade 3 was also independently associated with being overweight in the Sixth Grade after controlling for a child’s Third Grade weight status.¹³⁹

¹³⁷ Ibid.

¹³⁸ Ibid. p. S32

¹³⁹ Lumeng, J., et al. “Shorter Sleep Duration is Associated with Increased Risk for Being Overweight at Ages 9 to 12 Years.” *Pediatrics*. 2007. <http://pediatrics.aappublications.org/content/120/5/1020>

An additional study published in 2014 also links childhood obesity to reduced sleep during infancy and early childhood. The mothers involved in this study were recruited during early pregnancy, and followed their children from age 6 months to 7 years. These mothers were asked about their child's sleep duration as they aged, along with a variety of body measurements that were taken when the children were 7 years old.¹⁴⁰ Children were assigned a sleep score ranging from 0 to 13 based on the amount of sleep reported by their mother. A score of 0 specified the highest level of sleep deprivation whereas a score of 13 indicated no reports of deficient sleep. A lack of sleep for this study was defined as:¹⁴¹

- 6 months- 2 years old: less the 12 hours per day
- 3-4 years old: less than ten hours per day
- 5-7 years old: less than nine hours per day

The researchers of this study found that the children in households with lower incomes and lower maternal education were likely to have lower sleep scores. Minority children were also more likely to receive less sleep. When examining the relationship of sleep with body fat, Taveras et al. found that "chronic sleep curtailment throughout infancy to mid-childhood was associated with higher overall and central adiposity [body fat] at age 7 years."¹⁴²

¹⁴⁰ Taveras, E., M. Gillman, M. Pena, S. Redline, and S. Rifas-Shiman. "Chronic Sleep Curtailment and Adiposity."

Pediatrics. 2014. <http://pediatrics.aappublications.org/content/early/2014/05/14/peds.2013-3065.full.pdf+html>

¹⁴¹ "Chronic Insufficient Sleep Increases Obesity, Overall Body Fat in Children." Massachusetts General Hospital. http://www.eurekalert.org/pub_releases/2014-05/mgh-cis051414.php

¹⁴² Taveras et al., Op. cit., p. 1017

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