Adolescent Sleep: Effects of School Start Time on School Performance

by

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ABSTRACT

This study investigated the relationship between school start times and academic and school behavioral outcomes among adolescents. Academic achievement test data from five high schools in a Southwestern school district were compared prior- and post- a school start time change. Behavioral discipline reports were also examined to determine if earlier start times resulted in more behavioral problems for students. Results indicated minimal changes in academic achievement scores, with some significant differences between school start times when examining students' performance by pass/fail categories. Behaviorally, there were statistically significant differences between school start times with regards to high frequency referrals (i.e., attendance-related and defiance and disrespect towards authority), and total Office Discipline Referrals. Results are discussed in relationship to previous research on sleep and school start times along with the implications for adolescent school performance.

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Chapter 1

Introduction

There is a growing social concern regarding the sleep patterns of today's adolescents (Fallone, Owens, & Deane, 2002). As youth transition from childhood to adolescence, school-night sleep tends to decrease, and the gap widens between weekend and weekday sleep duration (Carskadon, 1990). The amount of sleep and sleep timing are factors that have been found to affect daytime functioning during adolescence (Wolfson & Carskadon, 1998). Much of teen daytime activity takes place at school, a fact that plays a significant part in teen sleep schedules by determining school start times. Evidence and common sense both suggest that sleep serves a restorative purpose and is an active period for the brain with regards to memory consolidation (Dement & Vaughn, 1999). When sleep debt accrues, studies have shown that sleepiness during the day increases and cognitive functioning is negatively affected (Carskadon, Harvey, & Dement, 1981; Wolfson & Carskadon, 1998).

Sleepiness is defined by Dement (1993) as "an awake condition that is associated with an increased tendency for an animal or person to fall asleep" (p. 554). Sleepiness is directly affected by internal circadian rhythms and homeostatic systems, which can be changed via biological, psychological, or environmental factors (Fallone et al., 2002). Fallone and colleagues (2002) noted that such factors can hide or reveal sleepiness, meaning certain factors (e.g., boring or calm activities) allow for its expression or temporarily stall sleepiness's external presence (e.g., exercise, competing physiological needs). Sleepiness is also affected by pubertal development, but overall, it appears that the amount of sleep needed by adolescents does not differ from that of elementary school age children, although there is some evidence of increased midday sleepiness during the middle stages of puberty (Carskadon, 1990).

Dornbusch (2002) encouraged a movement towards studying sleep's influence on adolescent functioning because adolescents who become engaged in more daytime activities may then experience fewer hours of sleep or poorer quality sleep, both of which have implications for a myriad of problems. These may include the development of sleep disorders, increased risk of motor vehicle accidents, and poor overall daytime functioning that can negatively influence work and school performance (Lamberg, 2009; Wolfson & Carskadon, 2003). These problems extend internationally and support for the relationship between sleep duration and quality and daytime functioning has been found in cross-cultural research (Dornbusch, 2002).

In the present study, adolescent functioning relative to sleep was studied indirectly by examining school start times. Studies have shown that earlier start times do not necessarily mean earlier bedtimes and those teens who attended a school with a significantly later start time (9:30 A.M. versus 7:30 A.M.) received an average of 30 minutes more sleep per weeknight (Kowalski & Allen, 1995). There has been a movement to postpone school start times across the nation thanks to previous sleep and school-start time related studies indicating the need for later times to fit the adolescent's sleep schedule (e.g., Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998, Wolfson, Spaulding, Dandrow, & Baroni, 2007), but the availability of research specifically addressing the relation between school-start time and adolescent performance is still somewhat limited with regards to the quantity and quality of sleep. Thus, the present study intended to help further the support for allowing adolescents to obtain more sleep during early-morning hours, prior to beginning the school day, by examining the effects of sleep indirectly through school start time on school-related factors (e.g., grades, attendance) for adolescent students.

Chapter 2

Literature Review

Sleep is a vital aspect of life that consumes a significant portion of each day. Humans spend, on average, about one-third about their lives asleep (Lima, Rattenborg, Lesku, & Amlaner, 2005). Given sleep's prominent presence in life, there has been great interest in uncovering the inner-workings of this phenomenon that is required for existence. Dement and Vaughn (1999) described sleep as "a miraculous journey made all the more extraordinary by this one simple fact: We never know we're sleeping while we're asleep" (p. 13). Dement and Vaughn also discussed two essential aspects of sleep related to this notion: a barrier between the conscious mind and the outside world, and the rapid reversibility that occurs during typical sleep. Crabtree and Williams (2009) offered an operational definition of sleep: "a state of decreased responsiveness and interaction with external stimuli" which is measured via observable behavior (p. 799). Although observable external behavior presents as a lack of activity during sleep, technology and research have also revealed the abundance of physiological and neurological activity that occurs internally (Crabtree & Williams, 2009). Thus, sleep is a basic drive defined both by the body's experience of external rest and internal activity.

Sleep Architecture

Sleep occurs over a series of stages which are described in terms of physiological and neurological behavior: Stages 1 through 4 and REM sleep. Prior to the first stage, an individual relaxes his or her body into a state of "calm wakefulness" and the quick-paced beta waves associated with full alertness transition to a slower form known as alpha waves (Dement & Vaughn, 1999, p. 19). Within a short time, these waves become theta waves which are at an even lower frequency and are associated with Stage 1 of sleep. During the first stage, it is fairly easy to be awakened, but sensory intake decreases as Stage 2 begins. Stage 2 consists of short (2-3 seconds) bursts of brain waves that are unique to sleep, sleep spindles and K-complexes. Both of these waves last just a last few seconds at a time, but sleep spindles are higher frequency bursts of waves and K-complexes are larger waves that come and go rapidly, seemingly "out of nowhere" (p. 20). At Stage 3, deep sleep begins and the delta waves emerge which make it difficult to detect the theta, sleep spindles and K-complexes that remain present. During the final descent into Stage 4, the latter three types of waves are nearly invisible as delta waves dominate this deepest level of sleep. During normal sleep, Stage 3 will re-emerge for a brief period of time before Rapid Eye Movement (REM) sleep brings back theta waves along with bursts of alpha and beta waves and a physiological paralysis as the voluntary muscles of the body do not move (Dement & Vaughn, 1999).

Depending on the developmental age of the individual, there will be several cycles of these stages, which typically include instances of dreaming (Dement & Vaughn, 1999). The cycles are sometimes referred to as basic rest-activity cycles (BRAC) as they include both deep and lighter sleep activity (Kleitman, 1993).The length of awake time influences the duration of certain stages. For instance, the longer an individual remains awake, the more slower wave, deep sleep, will occur once that person falls asleep (Dahl & Lewin, 2002). Slow wave sleep is inversely correlated with age, meaning that older age is associated with decreased amounts of deep sleep (Dahl & Lewin, 2002). In some cases, the slow delta waves and higher-frequency alpha waves can become intertwined (Hauri, 1993). Referred to as alpha-delta sleep, this can cause physical problems during wake-time such as pain and sleepiness and this phenomenon occurs in patients with arthritis or those who take stimulants in large amounts or over a long period of time (Hauri, 1993).

Sleep Components

Rapid Eye Movement (REM) and Non-REM (NREM). Sleep can be broken down into two main components, REM and NREM sleep (Colrain & Baker, 2011). Both types are detected and distinguished by fast and slow brain wave movements visible on EEGs (Colrain & Baker, 2011). These two types of sleep were distinguished when REM was first recognized by Aserinsky and Kleitman (1953) who studied sleeping infants. The connection between active brain waves and rapid eye movement in sleeping individuals instigated further research to learn more about REM sleep (Dement & Vaughn, 1999). Dahl and Lewin (2002) referred to REM sleep as “paradoxical” sleep because it consists of both light and deep sleep characteristics. Muscle tone loss and subcortical brain systems indicate deep sleep, while active higher cortical brain functions indicate lighter sleep (Dahl & Lewin, 2002). Non-REM sleep, which has received less attention in the literature (Salzaurulo & Gagioli, 1995), comprises the majority of sleep, during which these physiologic and neurologic behaviors are absent (Dement & Vaughn, 1999).

Circadian and Homeostatic Systems. A two-process model described by Borbely (1982) included a daily (circadian) rhythm of sleep propensity and sleep-wake pressure (homeostatic) system (Carskadon, 2011). The circadian rhythm is often thought of as the biological time clock because its role includes “timing and duration of daily sleep cycles” (Crabtree & Williams, 2009, p. 799) and it tends to follow a 24-hour cycle (Rosenburg, 1993). The circadian rhythm was discovered when this cycle persisted in organisms without environmental cues, defined as zeitgebers (Richardson, 1993). The circadian process is considered mature by the time an infant reaches three months of age (Crabtree & Williams, 2009). As described in Dement and Vaughn (1999) the biological clock, or circadian rhythm, “promotes wakefulness and actively opposes sleep” (p. 79). On the other hand, the homeostatic system regulates “length and depth of sleep” and is dependent on the “timing, duration, and quality of an individual’s previous sleep period” (Crabtree & Williams, 2009, p. 799). The homeostatic drive is what causes an individual to fall and remain asleep because the sleep debt accumulates during the day and this drive then puts the body to sleep to restore homeostasis, and return the sleep debt to zero (Dement & Vaughn, 1999).

Based on mammalian studies of the sleep process using monkeys, Edgar and Dement developed a similar model to explain the sleep processes, the Opponent-Process Model (Dement & Vaughn, 1999). The difference from Borberly’s (1982) model lies in its ability to “understand clearly why people tend to fall asleep or stay awake at any particular time of the day or night” (Dement & Vaughn, 1999, p. 79). It also explains why people do or do not fall asleep when they want to and “provides the basis for the personal insights” that allow sleep to become part of the “effective management of our individual lives and schedules” (Dement & Vaughn, 1999, p. 79).

Sleep Hormones. Integrated with the homeostatic process and circadian rhythm, hormones play an influential role in the sleep process. Melatonin is a hormone released at its highest rate during nighttime (Sbanaban, 1993). Melatonin production occurs in the pineal gland, with the retina as a secondary source, and the circadian timing systems regulate its release typically during nocturnal hours (Carskadon, 1999; Sbanaban, 1993). Research indicates that melatonin secretion in adolescents occurs later in the evening than it does in younger children (Lamberg, 2009). Carskadon (1999) recommends the measurement of melatonin secretion as a more precise way to assess changes in sleep patterns during child and adolescent development.

Sleep across Development

Sleep is a process that continually changes, especially during the first years of life and across childhood and adolescence. Crabtree & Williams (2009) described this transition of sleep patterns across development. During infancy, 64% of the child's day is spent at rest and as the child ages, the circadian rhythm becomes evident through the tendency to sleep more at night than during the day. They also note that infants have multiple, brief periods of sleep and that the amount of time spent in different types of sleep changes rapidly. Infants also experience basic rest and activity cycles (BRACs) of 50-60 minutes that include quiet and active sleep; active being a pre-REM type of sleep as they do not yet exhibit the muscle paralysis during REM that occurs at a later age (Crabtree & Williams, 2009; Kleitman, 1993). As the infant matures, sleep periods increase and the total amount of sleep decreases. The total duration of sleep decreases to 50-55% of the day by the one-year mark and the majority of the changes in sleep duration and periods occur between two and three years of age (Crabtree & Williams, 2009).

The change in sleep periods and amount of sleep continues as sleep onset moves from approximately 8:00 pm at one year to 9-9:30 pm by five years of age, while wake time remains near 7:00 A.M. (Crabtree & Williams, 2009). During this early childhood period, naps are common, as well as night-wakings (Crabtree & Williams, 2009). During middle childhood, the average amount of sleep is between nine and ten hours, or between 37% and 41% of the day (Crabtree & Williams, 2009). Humans increase their wakefulness from one-third of their day during infancy to about two-thirds at maturity and their BRAC increases to 85-95 minutes (Kleitman, 1993). The literature also indicates a gender difference between four and 12 years of age with respect to total sleep, with girls sleeping more than boys (Crabtree & Williams, 2009). The sleep and wake times shift to nearly 10:00 P.M. and 7:30 A.M., respectively during this stage (Crabtree & Williams, 2009). The amount of sleep needed remains the same as children transition to adolescence, but the ten hour average obtained by youth during middle childhood decreases to 7 ½- 8 hours of sleep per night as individuals approach 16 years of age (Crabtree & Williams, 2009). Later sleep and wake times also emerge during adolescence (Crabtree & Williams, 2009). The physiologic and neurologic changes in sleep during adolescence will be part of a later discussion that includes influences of the environment and effects on adolescent wellbeing, academics, and behavior.

Along with a general decrease in sleep time, both human and animal studies have found changes to the circadian clock that occur as we age including: increase in daytime sleeping and nighttime disruptions, early bedtime and wake times, and decreased tolerance for shift work and jet lag (Rosenburg, 1993). Such changes are speculated to be the result of environmental and lifestyle changes, rather than an actual change in the biological clock (Rosenburg, 1993). Either way, it is important to understand how the nature of sleep changes throughout the lifespan of every individual. Although the changes described follow the general developmental trend, variation among adults exists with regards to amount of sleep and timing of sleep that appear to be related to individual traits and differences in states, or "transient tendencies" (Webb, 1993a, p. 301). Some individuals, for instance, are considered to be "morning people" because of their tendency to wake up early, while others are considered "night owls" as they are likely to naturally stay up later (Jenni & O'Connor, 2005). These are the extreme versions of what is known as an individual's chronotype, or preference for sleep and wake time (Kirby, Maggi, & D'Angiulli, 2011). Jenni & O'Connor (2005) also emphasized differences created not only by biology, but also by culture.

Purposes and Benefits of Sleep

Sleep has benefits for our health that make it a vital and imperative part of our existence. The common belief that many still hold is that sleep's main purpose is to "rest the body", but Dement and Vaughn (1999) speculated that there is no direct evidence to substantiate this reason for sleeping (p. 243). They also acknowledged that the specific benefits and purpose of sleep are not completely clear and many theories exist that speak of a variety of possibilities (Dement & Vaughn, 1999). For example, while some theorize that sleep's primary purpose is to help with development, Salzarulo and Fagioli (1995) noted that it is difficult to separate the function of sleep versus wakefulness and their relative influences on development. Dement and Vaughn (1999) also agreed that there are now some uncertainties associated with such theories as the Roffwarg-Dement theory Roffwarg, Muzic, & Dement, 1966) which states that REM's primary function is brain development. This raises the question of why adults continue to experience REM after the brain is developed.

Dahl and Lewin (2002) agreed that sleep serves a restorative purpose and that it appears to be necessary for maturation. This restorative model has permeated the history of sleep. Dahl and Lewin also noted that sleep appears to be necessary for maturation. The restorative model is supported by correlational studies described by Dement and Vaughn (1999), including a 1950's American Cancer Society study and a study in Finland. Both found a link between amount of sleep and health or mortality. More specifically, individuals who slept an average of eight hours per night had a greater chance of living longer than those who slept significantly fewer hours per night, as well as those who got significantly more sleep. These authors described studies that have found support for sleep's relation with areas such as the immune system, cell repair, and vitality as well as psychological processes involving mood and mental health, making it an important consideration when treating both physical and emotional health problems.

In the 1970's, growth in the sleep-related field occurred, with a connection developing between medicine and sleep when researchers realized that the hours when a person was awake were not the only time that they could be treated. Another sleep model also emerged, referred to as the adaptive model (Webb, 1974). An alternative or addition to the restorative model, this model suggested that sleep serves an adaptive purpose for many animal species and accounts for the timing of sleep, whereas the restorative model "accounts for the results of sleep deprivation" (Webb, 1993b, p. 258). In the 1980's, Webb (1993b) noted that these two models were then combined into the previously discussed two-factor model introduced by Borbely (1982).

In addition to general studies of sleep, both types of sleep, REM and NREM, can be examined for purpose and function. However, REM is the only type that has been clearly studied. One theory, the ontogenetic hypothesis, postulates that REM sleep in particular is especially beneficial for brain and central nervous system development (Salzarulo & Fagioli, 1995). Support for this theory comes from studies that found a decrease in REM sleep in mammals as they age (Salzarulo & Fagioli, 1995). Others contend that sleep is necessary for memory consolidation (Diekelmann, Wilhelm, & Born, 2009). Diekelmann and colleagues (2009) found that slow-wave sleep assists the consolidation of declarative memory and REM enhances procedural and emotional memories.

Sleep Assessment

In order to understand sleep studies, one should be familiar with methods of sleep assessment. Sleep research is still fairly young and is improving subsequent to the development of more advanced technology, which has provided the opportunity to study what really happens while the body is asleep. Several methods are currently utilized to assess sleep: observation, questionnaires, interviews, actigraphy, videosomography, and polysomnography (Crabtree & Williams, 2009). A combination of these methods would allow for a behavioral, physiological, and neurological examination of sleep. Polysomnographies in a lab setting are considered the gold-standard for studying sleep in children, but they are also now used in the home setting to allow for more naturalistic studies (Crabtree & Williams, 2009). Polysomnography tracks sleep states including both REM and non-REM sleep based on a variety of physiological responses (Crabtree & Williams, 2009). Actigraphy, a small device worn on the wrist, is another more naturalistic method that measures movement during sleep that can be used for a more extended period of time compared to the polysomnography, but it can also lead to confounded data because of its dependence on movement to indicate wakefulness (Sadeh, 1993; Crabtree & Williams, 2009). Sleep deprivation is also a method of studying the need for certain types of sleep such as REM (Dement & Vaughn, 1999). In addition, brain waves can be observed using electroencephalograms (EEGs) and computer-based technology such as brain electrical activity mapping (BEAM) and computed electroencephalographic topography (CET) which also allows for methods of "displaying and analyzing large amounts of brain wave activity" (Pressman, 1993, p. 84).

One of the most popular sleep tests, developed in the 1970's by Carskadon and Dement (1977), is the Multiple Sleep Latency Test (MSLT). Essentially, the MSLT is one of the first objective measures of sleepiness, measured by the latency period between the point when an individual lies down to sleep and when he or she actually falls asleep (Dement & Vaughn, 1999). Carskadon and Dement (1979) demonstrated the value of the MSLT on sleep latency by examining the effects of loss of sleep in a small sample of 18 to 21 year old college undergraduates. This tool essentially pinpoints sleep debt, following the theory that the more debt accumulated, the more quickly a person will fall asleep. During a period of wakefulness, sleep debt is accumulated and for individuals with healthy sleep patterns, sleep will occur within 10-15 minutes. Although this discussion goes beyond the scope of the present study, the study of sleep and sleep debt is critical since sleepiness has been found to contribute to daytime activities such as driving a vehicle, alcohol consumption, and work or school performance (Dement & Vaughn, 1999).

Adolescents and Sleep

Jenni and Carskadon (2004) emphasized the delay in adolescent sleep onset as being one of the prominent findings in regards to adolescent sleep behavior. Hagenauer, Perryman, Lee, and Carskadon (2009) acknowledged the issue of sleep-deprived adolescents in today's society and attributed it to pubertal changes in the biological systems associated with sleep. These changes influence the delay of sleep that is seen among adolescents internationally. Recently, Matricciani, Olds, and Petkov (2012) reviewed sleep studies from around the world and found an overall decline in the amount of sleep at the rate of 0.75 minutes, nearly 1 minute, per year over the last century. The three factors most significantly influencing this decline in amount of sleep have been found to be gender, age, and school vs. non-school days (Matricciani et al., 2012).

As mentioned earlier, Jenni and O'Connor (2005) speculated that an interaction between biology and culture determines both behavior and developmental norms related to sleep. Relevant to the present study, US school start-times and demands for education are part of the culture that plays a role in sleep and will be examined in further detail following a discussion of the developmental changes related to sleep in adolescence.

Biological Changes Affecting Adolescent Sleep Across Development. Among the many changes occurring in youths' bodies as they move toward adolescence, studies show that puberty also affects sleep patterns. A self-report survey of sixth grade girls found that those who were more mature in terms of puberty preferred later sleep hours compared to their less mature peers (Carskadon, Vieira, & Acebo, 1993). Given the opportunity, adolescents are more likely to have later sleep and wake times as compared to their earlier childhood years (Carskadon, 1999).

Laberge et al. (2001) assessed sleep differences across gender and puberty development along with the relation among sleep patterns, habits, sleep difficulty, and nighttime waking. Canadian mothers completed surveys regarding their children who were between ten and 13 years of age. Over this developmental span, results showed evidence of decreasing sleep time, later bedtimes, and a larger gap between weekend and weeknight sleep schedules (Laberge et al., 2001). Even though adolescents overall were receiving less sleep, gender differences indicated that girls tended to spend more time in bed during the weekend than boys. Girls' tendency to reach mature pubertal status at an earlier age may be the reason for the gender differences found (Laberge et al., 2001).

Changes in the Circadian Rhythm and Homeostatic Process. During puberty, these two processes, the circadian rhythm and the homeostatic process may be undergoing changes that are affecting sleep patterns in adolescents. Some research supports the presence of a circadian rhythm shift in adolescence such that teens naturally fall asleep later and wake later than younger children (Crowley, Acebo, & Carskadon, 2007). Dahl and Lewin (2002) suggested three main changes in sleep during adolescence: 1) duration/organization, 2) timing of sleep/influence from biological clock or circadian rhythm, and 3) architecture within sleep. They also discussed important principles of the circadian rhythm. First, it adapts slowly to changes in sleep/wake schedules, which means adolescents' rapid shifts between school nights and weekends can be particularly problematic (Dahl & Lewin 2002). Secondly, the circadian rhythm adapts more easily to delays than to advances in the sleep/wake schedule (Dahl & Lewin, 2002). These particular issues, if severe enough, may lead to delayed sleep phase syndrome (DSPS) in adolescents (Crowley et al., 2007; Dahl & Lewin, 2002). DSPS refers to an "an inability to fall asleep and wake at a desired clock time, consistency in reported sleep times at later hours than other individuals, and otherwise normal sleep" (Crowley et al., 2007, p. 607). Consequences for adolescents with this issue might include sleep loss, disrupted sleep, excessive daytime sleepiness, and an impaired ability to awaken (Crowley et al., 2007). Such symptoms are likely to cause issues with daily functioning at school.

The circadian rhythm shows signs of delay via the endocrine system even in the controlled conditions of a laboratory setting (Hagenauer et al., 2009). A review of mammalian pubertal development also found evidence of a circadian phase delay in non-human species. In addition to a delayed circadian rhythm, these authors note that the homeostatic drive seems to work more slowly, meaning older adolescents tend to be able to resist the sleep pressure associated with the homeostatic drive and stay awake longer. There is also support for the role of light exposure and sensitivity in these changes and its effects on the homeostatic and circadian processes (Hagenauer et al., 2009). For example, Burgess and Eastman (2004) investigated the role of light exposure at night, finding that those who went to bed later delayed their circadian rhythm and that indoor light exposure can affect the circadian rhythm and delay melatonin production.

Sleep pressure and slow wave sleep, which are associated with the homeostatic process, are some of the most studied areas related to biological changes in sleep during adolescence. In 1980, Carskadon, Harvey, Duke, Anders, Litt, and Dement examined pubertal changes in sleep across three summers. Among the 19 participants, they found a consistency in nocturnal sleep time and REM sleep across the Tanner pubertal stages, but there was a 40% reduction in slow wave sleep across development and more report of daytime sleepiness in the third and fourth pubertal stages compared to the first and second stages despite similar amounts of nocturnal sleep (Carskadon et al., 1980). Carskadon (1999) hypothesized that the changes in slow wave sleep may be due to reduced biological pressure to sleep or structural changes in brain.

Carskadon, Acebo, Richardson, Tate, and Seifer (1997) utilized what was dubbed the “long nights” protocol which used phase markers under different Light-Dark (LD) conditions to examine adolescent circadian phases. In a small sample of youth 11 to 14 years of age (n = 19), it was found that adolescents tended to go to sleep later at night than younger youth. Carskadon et al.’s findings supported a relationship between circadian phase and adolescent development, including a significant correlation between the offset phase of melatonin secretion (when melatonin secretion dropped below a pre-determined amount) and age. This research continued when Carskadon, Acebo, and Jenni

(2004) also investigated changes in the homeostatic process and circadian rhythms in adolescence. They found that changed aspects of the homeostatic process allowed for later bedtimes in late adolescence and that EEG markers for the circadian rhythm, including: phase, period, melatonin secretion, light sensitivity, and phase relationships showed evidence of change during pubertal development with potential to alter sleep patterns substantially. Unfortunately, many adolescents appeared to have too little sleep at the wrong circadian phase, a mishap that heightens the risk of a multitude of behaviors: excessive sleepiness, difficulty with mood regulation, impaired academic performance, learning difficulties, school tardiness and absenteeism, and accidents and injuries (Carskadon et al., 2004).

At the same time, Jenni and Carskadon (2004) conducted an analysis of pre-pubertal and mature adolescents utilizing EEGs to detect developmental changes in sleep. This laboratory research study led to the conclusion that although slow-wave activity (SWA) decreased, the homeostatic process remained unchanged across adolescent development. The time course of SWA has been used to determine "parameters of the adult homeostatic process" (Jenni & Carskadon, 2004, p. 774), but it would appear that based on these results, developmental changes in the brain, rather than a change in the homeostatic process has taken place. Jenni and Carskadon also saw reduced NREM Stage 4 sleep and an increase in Stage 2 sleep in mature adolescents.

Jenni, Achermann, and Carskadon (2004) also found no difference between pre-pubertal and mature adolescents' homeostatic process during nocturnal hours. However, there appeared to be a differing rate of increase of the homeostatic process during wakefulness such that pre-pubertal adolescents have a lesser capacity to emit slow-waves when compared to mature adolescents and are therefore less likely to stay awake as late as more mature adolescents (Jenni et al., 2004). Jenni, Van Reen, and Carskadon (2005) further supported the notion that the homeostatic process remains stable over adolescence when examining EEG and polysomnographic recordings in 20 pre- and 20 late- pubertal participants. Jenni et al. had expanded upon earlier studies by examining regional differences in the brain using EEG, but the decay of the homeostatic drive, or sleep pressure, was similar among younger and older adolescents as measured by SWA.

Also interested in sleep pressure, Taylor, Jenni, Acebo, and Carskadon (2005) studied sleep tendency, or the latency until sleep onset after an individual goes to bed, as a means of determining if more mature adolescents experienced decreased sleep pressure before sleep onset as compared to younger adolescents. They independently assessed the influence of homeostasis and circadian phases and overall, the study supported a slower sleep pressure rate in older adolescents (Taylor et al., 2005).

More recently, Tarokh, Carskadon, and Achermann (2012) examined sleep homeostasis across these developmental stages using EEG recordings. They conducted a longitudinal cross-sectional study to assess children, adolescents and young adults, ages 9-23 years in a highly-controlled, laboratory setting. In contrast to Carskadon's (1980) and Taylor et al.'s (2005) findings, their results inferred no change in sleep pressure as measured by slow-wave activity (SWA) across adolescence, meaning that the sleep homeostasis process appeared to remain stable across adolescence (Tarokh et al., 2012). They hypothesized that a greater duration between dim light melatonin onset (DLMO) and sleep onset would result in greater sleep pressure, but such a correlation was not found, perhaps because the subjects had fixed sleep-schedules rather than self-selected schedules (Tarokh et al., 2012). The complexity of the association between the circadian phase and sleep homeostasis may have also played a role in the lack of a significant relationship.

Overall, the literature supports a biological change in sleep during adolescence, although the underlying mechanism is not quite clear. There appears to be a consensus that changes in the brain occur during adolescence that affect sleep, but there is some discrepancy among findings as to whether there is a change in slow wave sleep and the homeostasis process that produces the tendency for adolescents to fall asleep at a later time.

Psychological and Environmental Changes. In addition to the biological changes in sleep during adolescence, there are also psychological and socio-cultural influences that contribute to the problem of inadequate sleep. Moore (2012) notes that many sleep problems in children and adolescents go beyond medical sleep issues (e.g., obstructive sleep apnea, restless leg syndrome, parasomnias, etc.). There are sleep problems, some related to inadequate sleep, which are behavioral in nature and thus require behavioral interventions and treatment (Moore, 2012). For instance, many teens become more independent in determining their bedtimes, and other social and academic demands may contribute to later bedtimes (Carskadon, 1990, 2011). Crowley et al. (2007) described results from self-reports of adolescent sleep patterns from several countries. In general, adolescents' later bedtime behavior was associated with a number of environmental factors including: less reign from parents, more academic work, and extracurricular activities such as sports (Crowley et al., 2007). Carskadon (1990) also agreed that teens have more responsibility and higher expectations as compared to younger children with regards to academics, work, and social activities.

The most common sleep-related problem affecting adolescents is poor sleep hygiene, which encompasses issues with the timing and the environment in which sleep occurs and sleep and psychological habits that are beneficial for quality rest time (Moore, 2012). Those with inadequate sleep hygiene are likely among the group of adolescents described above who are not receiving enough sleep.

Looking more closely at sleep hygiene, Andrade, Benedito-Silva, Domenince, Arnhold, and Menna-Barreto (1993) conducted a longitudinal study examining the sleep characteristics of adolescents. Sixty-six healthy Brazilian adolescents were followed for about a year as they were given a physical examination and then completed sleep questionnaires at 6-month intervals (Andrade et al., 1993). Although none reported being poor sleepers, 60% reported experiencing daytime sleepiness and sleeping longer on the weekends - staying up later and waking up at a later time, which is not considered a good sleep habit (Andrade et al., 1993). Andrade et al. also found an increase in the conflict between social obligations and sleep as adolescents develop. Short et al. (2011) investigated the influence of parent-set bedtimes on adolescent sleep and daytime functioning in Australia. An 8-day diary, the School Sleep Habits Survey (Wolfson et al., 2003), and the Flinders Fatigue Scale (Gradisar, Terrill, Johnston, & Douglas, 2007) were utilized to gather information from 385 adolescents ranging from 13 to 18 years of age.

Only 17.5% of adolescents reported that a parent-set bedtime actually played a key role in their sleep habits on weeknights (Short et al., 2011). Those who did report such influence also showed that they went to bed earlier, thus sleeping more each night and had fewer sleepiness symptoms during the day (Short et al., 2011). In other words, parents' influence on sleep time appears to decrease as teens enter adolescence, thus increasing the likelihood that they will be staying up later than during earlier childhood years.

Another change in adolescence that often occurs with increasing independence is easy access to stimulating activities and social stresses, which likely relate to the academic and social demands (Dahl & Lewin, 2002). Stimulating activities include the use of technological devices, which is a change from earlier generations that can play a role in adolescent sleep. Two studies by Belgium researcher Van den Bulck (2004; 2007) examined the use of media (e.g., computers, television) and cell phones by adolescents during nighttime hours and its effects on sleep. The study in 2004 examined data from 2546 youth who completed the Leuven Study on Media and Adolescent Health which was gathered by the Leuven School for Mass Communication on Research in 2003. They found that youth with access to video games, television, and the internet in their bedrooms at night went to bed later and that overall these activities were related to poorer sleep patterns. Van den Bulck's (2007) study found that teens using their cell phones more after bedtime reported increased feelings of tiredness one year after the original data was collected. More recently, Morsy and Shalaby (2012) examined similar technology use in adolescents attending college and found a statistically significant relationship between technology use at night and insufficient sleep. Overall, there is emerging evidence suggestive of technology's role in the change in sleep during adolescence in recent years in addition to other environmental changes (e.g., bedtimes, social and academic stresses).

Inadequate Sleep during Adolescence. Given the critical importance of healthy sleep, its influence on adolescent functioning is a matter worth discussing. Sleep problems occur in about 30% of children (Liu, Liu, Owens, & Kaplan, 2005) and they affect several areas of functioning (Moore, 2012). A recent study found that nearly one-fifth of children in a US school district had symptoms of a sleep disorder (Ax & Bradley-Klug, 2007) and these problems extended into adolescence. A decade earlier, the National Institute of Health (1997) reported a concern for problem sleepiness risk in adolescents and young adults. Several studies suggest that the duration of sleep and sleep timing discussed in the previous section are also apt to affect performance in an adolescent's daily life. A longitudinal study conducted in 1976 at Stanford University indicated that the need for sleep did not change across children from 10 to 12 years of age (Carskadon, 1979). When given the same window of time to sleep, the children all slept about 9 hours and 15 minutes. This amount of time has also been supported by more recent literature from Cassoff, Knauper, Michaelsen, and Gruber (2012). They found that adolescents need about 9.2 hours of sleep per night, but 61% of those surveyed by the National Sleep Foundation (NSF) were not getting the recommended amount of sleep. Data from actigraphs indicate that the number of hours a youth sleeps decreases from ten hours during pre-adolescence to 7.5 – 8 hours of sleep by age 16 (Crabtree & Williams, 2009). In a cross-cultural study comparison, adolescents in China would found to sleep even less. According to parent reports, they had one hour less sleep as compared to children in the United States and also experienced more sleep problems (Liu et al., 2005).

In 2006, the NSF conducted a national sleep poll specifically targeting adolescents. They found that 45% of teens reported that they slept less than 8 hours a night; more than half reported feeling “too” tired and indicated that they got less sleep than they felt they needed. In addition, there appeared to be an awareness gap between parents and adolescents with respect to how much sleep adolescents were getting, meaning that parents believed that their youth were getting enough sleep most nights even though the teens reported that they were not.

Based on the NSF (2006) report that nine hours of sleep is optimal for adolescents, results from Jin and Shi’s (2008) self-report study found that an overall 64.6% of students, regardless of class time, received insufficient amounts of sleep. An additional 25.3% were in the borderline range of sleep duration and only 10.1% received at least nine hours of sleep on an average night (Jin & Shi, 2008). Jin and Shi (2008) also found a connection between students enrolled in AP/College courses and decreased amount of sleep.

Eaton et al. (2010) used the sleep questions from the CDC and Control and Prevention’s Youth Risk Behavior Survey (YRBS; 2007) to determine whether high school students received adequate amounts of sleep. The YRBS reports revealed that 68.9% reported insufficient sleep and only 7.6% reported receiving optimal amounts of sleep (Eaton et al., 2010). The remaining students were categorized as having borderline sleep, receiving about eight hours of sleep compared to the insufficient-sleep (less than seven hours) and optimal-sleep, (more than nine hours). Teufel, Brown, and Birch (2007) also surveyed early adolescents, ages nine to13, across several states to assess sleep deprivation issues. Only 14.1% of Teufel et al.'s participants reported sleeping the recommended amount of hours per night. Adolescents with more control over their bedtimes tended to be go to bed later and a significant relation was found between those adolescents with more bedtime control and sleep deprivation. The age of the adolescent was also related to amount of sleep, with older adolescents generally sleeping less than younger ones (Teufel et al., 2007). Defining inadequate sleep as less than seven hours per night more than one night a week, Smaldone, Honig, & Byrne (2007) also found a significant downward trend in adequate sleep with an increase in age (ages 8-17) in the 2003 National Survey of Children's Health.

Although youth appear to be receiving less sleep as they move into adolescence, the perceived need for sleep is still present. Strauch and Meier's (1998) longitudinal study found a high percentage of perceived need for more sleep across adolescents. Their study expanded across nearly ten years, with five survey distributions to high school students at two-year intervals. Overall, desired sleep was 1.7 hours more than what the adolescents reported receiving and those who perceived insufficient sleep also had more irregular sleep habits (Strauch & Meier, 1998).

Sleep inadequacy has also been recognized and studied in adolescents internationally. Manni et al., (1997) surveyed 869 adolescents in a northwestern Italian city and found that 16.5% of their sample reported symptoms suggestive of poor sleep quality. They also observed higher rates of sleep difficulties in girls as compared to boys (Manni et al., 1997). Additionally, Thorleifsdottir, Bjornsson, Benediktsdottir, Gislason, and Kristbjarnarson (2002) conducted a study in Iceland with a random sample of children (1 – 12 years old) and adolescents (13 – 19 years olds) selected from the National Register of Iceland. The 688 students who completed the initial survey were followed across ten years, with a follow-up every five years (Thorleifsdottir et al., 2002). An additional cross-sectional sample of 550 youth was collected in 1995 to compare to the original longitudinal sample. Results indicated a significant decline in sleep duration across age, with a shift to a later bedtime and fairly consistent wake-times except in adolescence during weekends in which wake-time moved to a later trend and then moved back by age 20. Sleep also increased on weekends through adolescence as did daytime sleepiness (Thorleifsdottir et al., 2002).

Effects of Inadequate Sleep. Youth who receive inadequate sleep were found to be more likely to have family conflict, to be perceived as difficult by their parents, and to not feel safe in their schools or neighborhoods (Smaldone et al., 2007). Specifically for adolescents, those with inadequate sleep were more likely to have parental reports of allergic conditions, frequent or severe headaches, as well as poor parental emotional health (Smaldone et al., 2007). More recently, Roberts, Roberts, and Xing (2011) utilized a large sample size of 11 to 17 year-olds to investigate restricted sleep (i.e., six hours or less) and its risk factors. Data was obtained from the Teen Health (2000) survey collected from a southwestern population and included two waves of data in which the second wave was a one-year follow-up of the original sample (Roberts et al., 2011).

Similar to earlier studies, restricted sleep is fairly prevalent among adolescents and additionally, was found to persist at the one year follow-up. The following characteristics predicted persistence for inadequate sleep: female gender, being older, schoolwork and school activities, school-related stress, and parent-relational stress (Roberts et al., 2011).

The effects of inadequate sleep among adolescents has been well studied, and previously discussed studies have already shown evidence of increased sleepiness during the day reported by teens receiving inadequate sleep. Effects of three sleep-related variables were examined by Acebo & Carskadon (2002). These included: 1) school-night sleep, 2) regularity of bed-time schedule, and 3) location of sleep. Several outcome measures indicative of daytime functioning were assessed using an extensive sleep habits survey that was administered to a large sample of high school students across several school districts in Rhode Island. Control variables considered to have potential influence on sleep and daytime functioning were also included (e.g., sex, race, age, caffeine and drug use). Even after controlling for all of these influential factors, sleep variables played a role in predicting daytime functioning. In particular, total sleep time appeared to be a significant predictor in this study. Regularity of sleep was related to factors not affected by total sleep time, such as grades, injuries associated with drug/alcohol use, and days spent home from school. It was also shown that students who slept less on school nights tended to stay up later on weekends and exhibited more phase delay-related behaviors. Overall, Acebo and Carskadon demonstrated the importance of sleep regularity, duration, and location for daytime functioning, including functioning related to school such as attendance and grades.

In an earlier study, Carskadon et al. (1981) examined effects of sleep loss among 12 adolescent subjects. The teens slept in small groups in a laboratory for six days. After one day was given to the subjects to adapt to the new sleeping environment, the experiment included two baseline days, one day of sleep deprivation, and two days of recovery. EEGs were recorded and performance tests administered at three different time periods across each day. The test battery included a Wilkinson Addition Test (Wilkinson, 1968), Williams Word Memory test (Williams, Gieseking, & Lubin, 1966), a listening attention task, and a serial alternation test. Daytime sleepiness ratings were collected from the subjects and the MSLT (Carksadon & Dement, 1977) was used to objectively measure daytime sleepiness. Impaired performance was observed on the measures given after sleep deprivation, with the addition and memory tests reaching statistically significantly lower levels. Results were similar to earlier adult sleep deprivation studies from other researchers, including the MSLT findings (Carskadon et al., 1981).

Cognitive performance was also investigated by Randazzo, Muehlbach, Schweitzer, and Walsh (1998) in a study including a small sample of randomly assigned youth ten to14 years of age. Youth were administered various cognitive functioning tasks including: subtests from the Wide Range Assessment of Memory and Learning (WRAML; Adams & Sheslow, 1990), the Torrance Tests of Creative Thinking (TTCT; Torrance, 1990), Children's Category Test (CCT; Boll, 1993), Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Tally, Kay, & Curtiss), and the California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1994). The youth who were assigned to the sleep restricted (i.e., five hours) group had short latencies on the MSLT and (Carskadon & Dement, 1977) showed impairment on higher cognitive functioning tasks as compared to the control group who had been given 11 hours in bed (Randazzo, Muehlback, Schweitzer, & Walsh, 1998).

In addition to memory and academic difficulties, researchers have also found that sleep deprivation is associated with behavioral and emotional difficulties. Primary insomnia may affect adolescents who experience anxiety about sleep and therefore have difficulty falling asleep, waking up too early, and staying asleep (Moore, 2012). Roberts, Roberts, and Chen (2001) examined data from a large sample of students ranging from ten to 17 years of age with a diverse ethnic background. Results indicated significant correlates of insomnia in adolescents with mood disturbance, suicidal ideation, unhappiness, interpersonal problems, and poor perceived health (Roberts et al., 2001). More recently, Noland, Price, Dake, and Telljohann (2009) found that high school students (n = 384) from a convenience sample of 9^{th} to 12^{th} graders with less sleep (7.5 hours) had higher perceived stress levels as compared to students with longer sleep durations (9.7 hours). In addition, many of the students also reported the following side effects of inadequate sleep: feeling more tired, attention problems, poor grades, and issues with interpersonal relations (Noland et al., 2009).

Inadequate sleep has also been correlated with higher levels of anxiety, depressive symptoms, and fatigue/sleepiness on the days following the low-sleep nights as found when Fuligni and Hardway (2006) studied a large sample of adolescents 14 to 15 years of age utilizing a daily diary method to examine three aspects of daily life: sleep time, activities, and psychological well-being. Furthermore, Gangwisch et al. (2010) found emotional risks related to inadequate sleep when examining bedtime as an indicator of sleep duration. In a large-scale study of 15,569 adolescents in middle and high school, parent-set bedtimes of 12 A.M. or later resulted in adolescents with increased risks of depression and suicidal ideations as compared to students with 10 P.M. or earlier bedtimes (Gangwisch et al., 2010).

Mercer, Merritt, and Cowell (1998) surveyed a convenience sample of 612 Midwest high school freshman using the Sleep Patterns Questionnaire (SPQ; Mercer et al., 1998), developed from a compilation of previous researchers' work and Mercer et al.'s (1998) contributions, and found that the majority of students (63%) expressed a perceived need for more sleep on weeknights, difficulty sleeping, and negative effects of daytime sleepiness on schoolwork. Those who reported that they needed more sleep also reported more symptoms of tiredness and had higher scores on depressive mood items compared to those who felt that they received sufficient sleep on the weeknights. Interestingly, these two groups had quite similar sleeping patterns, but different perspectives of their daytime experience, quality of sleep, and when they felt most awake during the day. The amount of sleep considered ideal was also one hour higher for those who had the perceived need for more sleep. Mercer et al. (1998) concluded that individual differences may be emerging in adolescence that may explain some of these discrepancies. It is also worth mentioning that depression can lead to feelings of fatigue as well as insomnia, so the connection between inadequate sleep and depressive symptoms is most likely correlational rather than causal.

Sleep restriction was utilized in a more recent study to investigate the effects of inadequate sleep on anxiety levels measured during a task rather than via retrospective self-reports. Talbot, McGlinchey, Kaplan, Dahl, and Harvey (2010) conducted an experimental sleep study in which sleep was restricted across three age levels: early adolescence, middle adolescence, and adulthood. The authors administered an affective functioning battery to groups of sleep-deprived (six and a half hours on first night followed by 2 hours on the second night) and non-sleep deprived individuals (seven to eight hours each night), finding that the latter group demonstrated more positive affect than those who were sleep-deprived. Anxiety levels were also higher in those who were sleep-deprived when given a catastrophizing task compared to the rested group. The catastrophizing task involved an interview that began with an identified threat designed to raise anxiety in the client. Then, a series of questions were asked regarding what worried the client about that threat, with their answers followed by the same questions until the client could no longer answer (Talbot et al., 2010).

Further support for the negative effect of sleepiness on daytime functioning was found in a review by Fallone, Owen, and Deane (2002). The relationship of inadequate sleep to behavioral difficulties was found to be especially robust; however, the inconsistency of behavioral consequences across the studies reviewed did not allow for any more specific conclusions except for decreased positive mood and increased parent-reported behavioral difficulties (Fallone et al., 2002). Although there is a suggestion made in the studies reviewed that cognitive functions such as flexibility are impaired, further data is also needed to support the predictability of the effects of sleepiness on these functions due to some inconsistent evidence regarding certain neuropsychological functions such as memory and attention (Fallone et al., 2002). Most of the research implicating the effect of sleepiness on youth has relied on self-reports rather than objective measurements such as the MSLT (Carskadon & Dement, 1977). Thus, further research utilizing these objective measures is suggested as a means to confirm and strengthen support for the effects of sleepiness on youth.

Adolescent Sleep and School Performance

As shown in the literature, sleep problems can affect many areas of functioning; of particular interest in the present study is the relation between sleep and school performance, both academic and behavioral. Adolescents spend a large majority of their day in school or completing school-related activities (e.g., homework), thus sleep's influence on their performance in the school setting would not be completely unexpected. Dewald, Meijer, Oort, Kerkhof, and Bogels, (2010) conducted three separate meta-analyses, covering the association between academics and three different sleep factors: quality, duration, and sleepiness. All three were modestly significantly related to school performance, with sleepiness noted as the strongest predictor (Dewald et al., 2010). Carskadon (1999) discussed several school-related behavioral factors that may affect adolescent sleep: change in parental involvement in sleep schedule; increased social opportunities and academic demands, employment, and school schedule - earlier because of bus schedules, local sunrise, and sports team schedules.

All of these factors may result in youth attending school feeling the effects of inadequate sleep. Drake et al. (2003) developed a measure of daytime sleepiness called the Pediatric Daytime Sleepiness Scale (PDSS) and found that of the 450 participants, those who had higher levels of daytime sleepiness were more likely to report the following: low amounts of sleep; more bouts of illness; higher school-absenteeism; and lower levels of school enjoyment and achievement (Drake et al., 2003). Also related to school functioning, the National Sleep Foundation (NSF; 2006) found that 25% of students fall asleep at least once a week in school, and students reporting optimal sleep have above average grades whereas insufficient sleepers were more likely to have lower grades. Perceived mood was also related to amount of sleep, with unhappy or tense students reporting higher levels of insufficient sleep, but again, this relationship is correlational and may not be causal (NSF, 2006).

Academic performance can be affected by the ability to utilize working memory efficiently. Thus, Gradisar et al. (2008) examined the link between sleep loss and working memory performance in a sample of 143 adolescent volunteers who completed a self-report survey. Gradisar et al. (2008) grouped participants according to sleep duration: sufficient (greater than nine hours), borderline (eight to nine hours), and insufficient (less than eight hours). The only significant difference among the groups was on two working memory specific tasks (letter-number sequencing, and operation span task) in which the insufficient-sleep group performed more poorly than those in the borderline-sleep group. However, compared to the other groups, those who received less than eight hours of sleep per night were significantly more likely to go to bed later, feel sleepier during the daytime, and take more time to fall asleep (Gradisar et al., 2008).

Jin and Shi (2008) conducted a survey study across 15 high schools in Iowa to investigate differences in sleep duration between students enrolled in Advanced Placement (AP) or college courses and those who were in non-advanced courses. They found an increased rate of insufficient sleep in those who took at least one AP/college course compared to those who did not, suggesting that students with a heavier academic load may be spending less time sleeping and more time studying. However, they did not examine GPA or grade differences between students who reported insufficient sleep and those who reported sufficient sleep (Jin & Shi, 2008).

Gray and Watson (2002) were interested in the connection between personality and sleep, and their combined effect on outcomes such as academic performance. Specific to sleep and academic outcomes, college students who had more regular sleep habits with regards to sleep and wake times had better grade point averages. Better sleep quality also improved well-being and psychological functioning in Gray and Watson's (2002) sample of undergraduate students. Duration of sleep, however, was not significantly related to any long-term outcomes of well-being.

Although no significant relation existed between sleep duration and long-term well-being in the study completed by Gray and Watson (2002), Kelly, Kelly, and Clanton (2001) did find a significant correlation between the amount of sleep and academic performance in a sample of college students. More specifically, self-reports revealed that individuals who slept a relatively short amount of time (six hours or less) had significantly lower GPAs as compared to individuals who slept more than nine hours (Kelly et al., 2001). However, it should be noted that extraneous factors such as employment and hours available to study were not controlled or accounted for in this study.

Internationally, there have several more studies connecting sleep and school performance in adolescents. In the Netherlands, Hofman and Steenhof (1997) examined adolescent sleep in relation to school performance among a total of 604 adolescents 12-18 years old and found a positive relation between school performance and sleep quality and duration. While this may provide some international support for the connection between sleep and school achievement, the measure of school performance was undefined in this brief article and other details regarding the analysis were not clearly described.

Warner, Murray, and Meyer (2008) conducted a longitudinal survey with 310 Australian high school seniors to examine the link between sleep and daytime functioning. Student reports indicated significant sleep debt that negatively affected mood, functioning, and academic grades. Those students whose circadian preference oriented them towards staying up later in the evening were most at risk for negative outcomes.

Meijer, Habekothe, and Van Den Wittenboer (2000) examined the relation between sleep and school functioning in Dutch youth nine to 14 years of age. Psychosomatic and neurotic symptoms were controlled due to their strong relationship with sleep quality. Sleep factors including time in bed and quality of sleep and school functioning was determined by self-report questionnaires that addressed the following: attention to teacher, boredom, achievement motivation, self-image related to school performance, and control over aggression. A positive relationship was found between quality of sleep and all school functioning factors with the exception of boredom. Low correlations between sleep quality and difficulty waking and feeling well-rested may have been a result of how sleep time was measured -- time in bed, rather than via more objective physiological measures such as EEG. Another notable finding related to time in bed was the lack of connection between concentration and sleep time and quality (Meijer et al., 2000). This is corroborated by Epstein et al.'s (1998) study of Israeli students, but differs from studies that found effects of sleep deprivation on cognitive performance (Carskadon et al., 1981; Randazzo et al., 1998). This discrepancy may be accounted for by the differences in type of cognitive measurement and amount of sleep deprivation between studies.

A comprehensive review of the few studies that have been published since the 1980's examining the relation between sleep habits and academic performance was conducted by Wolfson and Carskadon (2003). These studies were primarily based on self-report data and were not comprehensive with regards to measuring aspects of academic performance and sleep quality. The population of students examined ranged from middle school to first-year college students. A challenge found in this particular area of study is determining the best method of measuring school performance and there are several variations among these and other studies (Wolfson & Carskadon, 2003). These prominent adolescent development researchers have suggested that actual grades reported by the school or self-report data, although somewhat subjective, tend to be the best measure compared to standardized achievements or intelligence tests. Despite all of the limitations, these studies consistently support the relationship between sleep and academic performance such that impaired sleep is related to impaired academic performance.

One of the only studies found that contested this relationship was conducted among middle and high school students in Maryland schools (Eliasson, Eliasson, King, Gould, & Eliasson, 2002). This study utilized students from science classes in high school and a 200-student convenience sample from the seventh grade in middle school using a questionnaire developed by the researchers in which students self-reported their grade point averages (GPAs). The result did not reveal any significant connection between total sleep time and academic performance in the preliminary analysis (Eliasson et al. 2002). The authors suggested that school location in regards to latitude and sunlight may impact the effects of school start times, indicating a need for more research in a variety of geographic areas across the United States. The wide age range may have also played a part in the lack of significant findings from this particular study.

Relation between Sleep and School Start Time. Despite biological factors and social tendencies that result in later bedtimes for adolescents, they are still required to awake early in the morning on weekdays to attend school (Carskadon, 1990). In a preliminary study investigating the historical trends of school start times, Carskadon and Acebo (1997) found that internationally, schools that had historically started earlier had even earlier start times in recent years, whereas schools with later start times tended to stay consistent across time (Carskadon & Acebo, 1997). More recently, it was found that from 1986 to 2001, school start times had not significantly changed for high schools, with a mean start time of 7:55 AM (Wolfson & Carskadon, 2005). In many school districts, the start time is earlier for high school students than elementary school students, even though studies have shown the presence of delayed sleep patterns in teens (Carskadon, Vieira, & Acebo, 1993; Carskadon, 1999; Laberge et al. 2001).

Complementary to Kowalski and Allen's (1995) finding that later school start times resulted in more sleep, Carskadon et al. (1998) studied forty 9th and 10th grade participants who experienced a change in school start time from 8:25 A.M. to 7:20 A.M. and found that students' wake time moved up 25 minutes even though their bedtime stayed the same. This means that students received less sleep with an earlier school start time because they still fell asleep at approximately the same time despite an earlier start time (Carskadon et al., 1998). Carskadon et al. used the MSLT (Carksadon & Dement, 1977) test to measure the speed of falling asleep across repeated 20-minute trials in standard conditions and found that the earlier start time was correlated with significant sleep deprivation and daytime sleepiness. Thus, school start times have been shown to affect adolescent sleep and these studies support the inference that earlier school start times correlate with less sleep for adolescents.

Effects of School Start time on Academic Performance. In a study by Kowalski and Allen (1995), preliminary results suggested that a gap between weekend and weeknight sleep time had a negative effect on grades. One way to decrease this gap is to change school start times so that students are getting up at more similar times on weekends and weekdays. This notion to help remedy adolescent sleep issues by delaying school start times has permeated the Minneapolis Public School District (Noland et al.,

2009) and Minneapolis has therefore been a location where the relation between school start time and academic performance has been examined. The Minnesota Medical Association (MMA) became a leader in policy change and inspired further research in adolescent sleep needs in 1993 when they passed a resolution that effectively resulted in Minneapolis being the nation's first school district to adopt delayed school start times "based on science evidence of physiological changes in sleep needs and patterns associated with puberty" (National Sleep Foundation, 2000, p. 22).

Inspired by a delay in start time at a single high school in Minnesota, the school start times in all of the Minneapolis Public Schools were delayed by thirty minutes (from 8:40 A.M. to 9:10 A.M; Walhstrom, 2010). Walhstrom (2010) studied the effects of the change for the school district. An executive summary of the Minneapolis Public Schools Start Time Study was published in 1998 that described the city-wide school-based study (Wahlstrom, Wrobel, & Kubow, 1998). Wahlstrom et al. (1998) described a stratified random sample of 471 students across three different high schools, 599 students across a sample of middle school students, 48 student council members, and a sample of high and middle school students from another urban school with an earlier start time. All students participating in the study were administered the School Habits Sleep Survey (Wahlstrom et al., 1998).

Students from Minneapolis reported getting an average of 45 minutes more sleep than the comparative districts (Wahlstrom et al., 1998). The difference was 6 hours and 48 minutes compared to 7 hours and 27 minutes of sleep, and the key part is that the Minneapolis students were getting sleep during what is considered a critical point in the sleep cycle -- early morning. The Student Council Members, however, did not report the same benefits as their classmates even though they slept similar amounts of time, suggesting there may be differences between students who are more active in sports and extracurricular activities and those who are not (Wahlstrom et al., 1998).

With regards to academic achievement, students from Minneapolis Public Schools reported higher grades, which may be influenced by the increased amount of sleep (Wahlstrom et al., 1998). Other reasons such as grade inflation may be attributable to this difference, and this was supported by the report that Minneapolis students spent less time doing homework. It was noted, however, that final conclusions would be drawn after three years' worth of student data had been retrieved and studied (see Wahlstrom, 2002 below). The primary survey data regarding student behavior via teacher report indicated more alertness of students in the first two periods of school. On the negative side, there were some transportation delays in the mornings and issues with students leaving their last period early for athletic events (Wahlstrom et al., 1998). The follow-up study reported on the first longitudinal study of later high school start times utilizing data gathered from the Minneapolis Public School District (Wahlstrom, 2002). Data files of student grades and attendance were examined from three years prior to the change and three years after the school-start time change during the 1997-1998 school year and the School Sleep Habits Survey developed in 1994 by the Bradley Hospital/Brown University Sleep Research lab was re-administered. Data files from the schools included information on attendance, ethnicity, tardiness, graduation rates, and rates of continuous enrollment and information from the previously completed student surveys was also accessible.

Examining letter grades proved to be a complex and time-consuming task due to variation in factors such as course titles and the result was a slight, but not statistically significant improvement in overall grades (Wahlstrom, 2002). The self-report surveys from students were comparable to the data point analysis and overall it was noted that using letter grades to judge effects of school start time on grades is a difficult task. Symptoms of sleepiness and depressive symptoms were found to be significantly less for students with the later start times as indicated by the self-report student surveys. One of the central findings when comparing the survey from year one to year four after the start time change is that students continued to get an hour more sleep each weeknight than before the change (Wahlstrom, 2002).

Wolfson and Carskadon (1998) have also investigated the impact of school start times on the grades and attendance rates of high school students. Utilizing the Sleep Habits Survey developed in 1994 in the Bradley Hospital/Brown University Sleep Research lab, reports from 3,120 high school students were indicative of better school-related performance when school start times were later, even with only a difference of 20 minutes across the four schools included in the sample (Wolfson & Carskadon, 1998). Looking at the overall school day, Hansen, Janssen, Schiff, Zee, and Dubocovich (2005) utilized daily sleep diaries, neuropsychological tests, and mood and vigor tests to assess the impact of the high school schedule on adolescent sleep and performance. Overall, the sixty participants tended to lose nearly two hours of sleep per weeknight during the school year compared to the summer weekdays and they slept similarly on weekends as during summer weekdays (Hansen et al., 2005). Furthermore, Hansen et al.'s (2005) findings indicated that the students performed better on the tests in the afternoon and students in early morning classes reported feeling sleepier and less alert.

There have also been studies conducted at the middle school level that examined the relation between school start time and school performance. Wolfson et al., (2007) investigated the effects of early and later school start times on sleep and subsequent daytime performance. The sample of 205 students from two schools was matched on demographics and the students were asked to complete the Sleep Habits Questionnaire (Carskadon, Seifer, & Acebo, 1991; Wolfson & Carskadon, 1998) and Adolescent Sleep Hygiene Scale (ASHS: Harsh, Easley, & LeBourgeois, 2002). Academic performance, attendance, and tardiness were collected from school data. Results similar to those of Wahlstrom's (2002) high school findings were demonstrated with the middle school students, indicating benefits in sleep duration, average letter grades, and attendance/tardiness for students with later school start time (Wolfson et al., 2007). Most recently, Edwards (2012) conducted a large-scale secondary data study to examine the effect of school start times on academic performance of all middle school students in a single district from 1999 to 2006. Utilizing student percentile scores on standardized reading and math tests given at the end of the school year, Edwards found that a one hour later school start time was correlated with a significant 3 percentile point gain in both reading and math, with students at the lower end of the distribution benefiting more. When only looking within schools rather than across, a smaller effect occurred on reading and math grades (2 percentile points and 1 percentile point, respectively), but among all students, reduced sleep and adolescent hormonal changes were proposed as reasons for school start times to affect academic performance (Edwards, 2012).

Socio-emotional and Behavioral Factors and School Start Time. The available research regarding school start times and its effect on behavioral factors aside from academic performance is relatively scant.

In one of the studies conducted in the Minneapolis school district described earlier, the scores on the depression sub-scale of the survey were significantly lower for the Minneapolis high school students, who also reported less sleepiness symptoms after school start times were moved to a later time (Wahlstrom et al., 1998). Additionally, initial analyses revealed a modest increase in high school attendance rates in Minneapolis Public Schools in the first year after the change in start time. Follow-up analysis in a later report indicated that continuous enrollment in the district increased and when looking at attendance rates, no significant differences were found for students who were continuously enrolled, but students who were not continuously enrolled for two consecutive years experienced a statistically significant rise in attendance rates, 72% to 76% (Wahlstrom, 2002). Wolfson et al.'s (2007) previously described study also indicated improvements in attendance rates when delaying school start time, but students who were continuously enrolled were not differentiated from those who were not continuously enrolled as it was in the study conducted in 2002.

Owens, Belon, and Moss (2010) examined effects of delaying school start time by 30 minutes with regards to sleep, mood, and behavior of adolescents. A retrospective online Sleep Habits Survey (SHS; Wolfson & Carskadon, 1998) administered at a high school in Rhode Island to students in 9^{th}-12^{th} grade indicated that as sleep duration increased, motivation improved, and sleepiness and associated symptoms decreased. With regards to mood, depressed symptoms decreased and class attendance also improved (Owens et al., 2010).

Adolescent School Sleep Interventions. Lamberg (2009) reported on the status of schools with delayed start times. In the last 10 years, informal reports from the National Sleep Foundation (NSF) have found that more than 80 school districts in the United States have delayed their high school start times. Although it is a challenge for many school districts, Lamberg noted that districts were attempting to adapt to adolescent biology, which seems to have later melatonin secretions as compared to their younger counterparts which may delay bedtime and decrease total nighttime sleep duration.

Kirby et al. (2011) discussed the research related to delayed phase performance (DPP; Mitru, Millrood, & Mateika, 2002), which refers to the change in sleep cycle during adolescence. They indicate three prominent factors related to adolescent sleep that are empirically supported and may assist in determining appropriate school start times: sleep debt, performance on executive function tasks, and synchronicity effects (Kirby et al., 2011). Synchronicity occurs when "optimal performance is generally achieved at the peak time of day as determined by chronotypology," or a person's preference of time when they sleep and are awake (Kirby et al., 2011, p. 57).

Aside from changing school start times, few sleep interventions have been conducted, and those conducted have been within the last few years. For example, Cain, Gradisar, and Moseley (2011) recently developed a motivational school-based intervention in Australia in an effort to improve sleep and daytime functioning in their students at three secondary schools. Using a control and intervention group, they found that the intervention group, who attended a sleep education class each week, showed an increase in sleep knowledge along with a higher motivation to increase sleep times, but the sleep and daytime functioning improvements did not reach significance when compared to the control group (Cain et al., 2011). Similar findings were reported in a review of school-based sleep promotion programs reviewed by Cassoff et al. (2012) – although the programs increased knowledge, they generally had little effect in changing sleep behavior. They recommended that more individualized interventions be developed such as developing personalized computer programs that educate students about sleep and assisting with motivational problems that may impede healthy sleep habits (Cassoff et al., 2012).

Statement of the Problem

Adolescents who are required to attend school at earlier start times may be getting less sleep compared to students in schools who have adjusted their start times to better align with the typical adolescent circadian rhythm. Although there are several other factors that affect the amount of sleep youth obtain, school start time is a consistent factor that affects them on a daily basis and studies do show evidence for school start time playing a role in adolescents' reduced sleep time. Dahl and Lewin (2002) note that there is little empirical data examining effects of sleep deprivation and insufficient sleep among adolescents. Thus, the present study will empirically examine sleep indirectly through school start times and its effects on behavioral and academic performance.

Research Questions and Hypotheses

1. Does a later versus earlier school start time affect the reading performance of high school students as measured via standardized reading achievement assessments?

   Hypothesis: High school students attending school at a later start time will demonstrate higher reading performance as measured by a standardized reading achievement assessment as compared to students in an earlier start time group.

2. Does a later versus earlier school start time affect the mathematics performance of high school students as measured via standardized mathematics achievement assessments?

   Hypothesis: High school students attending school at a later start time will demonstrate higher mathematics performance as measured by a standardized mathematics achievement assessment as compared to students in an earlier start time group.

3. Does a later versus earlier school start time affect the writing performance of high school students as measured via standardized writing achievement assessments?

   Hypothesis: High school students attending school at a later start time will demonstrate higher writing performance as measured by a standardized writing achievement assessment as compared to students in an earlier start time group.

4. Does a later versus earlier school start time affect the science performance of high school students as measured via standardized science achievement assessments?

   Hypothesis: High school students attending school at a later start time will demonstrate higher science performance as measured by a standardized science achievement assessment as compared to students in an earlier start time group.

5. Does a later versus earlier school start time affect the number of overall discipline referrals received by high school students?

   Hypothesis: High school students attending school at a later time will have received fewer discipline referrals overall compared to students in an earlier start time group.

6. Does a later versus earlier school start time affect the amount of referrals received during the first period of the day?

   Hypothesis: High school students attending school at a later start time will have received fewer first-period referrals compared to students in an earlier start time group.

7. Does a later versus earlier school start time affect the number of attendance-related (i.e., truancy, tardy, leaving school grounds without permission, unexcused absence, other attendance issues) discipline referrals?

   Hypothesis: High school students with a later school start time will have received fewer attendance-related discipline referrals compared to students in an earlier start time group.

8. Does a later versus earlier school start time affect the number of defiant, disruption, and disrespect discipline referrals?

   Hypothesis: High school students with a later school start time will have received fewer defiant, disruption, and disrespect discipline referrals compared to students in an earlier start time group.

Chapter 3

Method

Participants

Data was obtained from archival school-records from a large public school district in the Southwestern United States. The participants included a subset of students from the 2009-2010 school year and students from the 2010-2011 school year across all five high schools (i.e., School 1, School 2, School 3, School 4, School 5) in the district. Each of the five high schools changed the school start time by 30 minutes, similar to the change in the Minnesota public schools (Walhstrom, 2010). The start time moved from 8:15 A. M. in the 2009-2010 school year to 7:45 A. M. in the 2010-2011 school year. The five schools had a total student enrollment of 8,840 during the 2009-2010 school year, which increased by only two students, 8,842, the following school year. Percent of free and reduced lunch, an indicator of socioeconomic status (SES), was as follows across the five high schools according to data available during 2010-2011 school year: 25%, 4%, 63%, 21%, and 6%. Table 1 provides a breakdown of enrollment percentages by school, including student population, ethnicity, and gender.

Arizona Instrument to Measure Standards *(*AIMS) participants. AIMS tests are typically first given in 10^{th} grade and only students who do not pass it during that year will take it again. Thus, although the AIMS data set included all grade levels, only 10^{th} grade students were included in the present study from each school year, with the exception of 9^{th} graders who took the AIMS Science assessment for the first time. This was done to remove potential confounding variance associated with students who took the test multiple times. School, gender, Special Education enrollment, and ethnicity were available via AIMS databases. There were two ways in which ethnicity had been identified in the data, a numbered/categorized column, and a series of true/false columns across six possible ethnic categories. Some subjects were missing data from one of the two methods of reporting ethnicity. One column was used as the primary source to determine ethnicity and the second set of ethnic data was used if the first column was missing. Some of the true/false columns had true marked for multiple ethnic categories, including white, so white selected for each case in which this occurred because a multi-racial code was not available (less than 25 cases total). Table 2 displays descriptive statistics of the AIMS data, which is described below across academic subjects.

AIMS Reading Demographics. Overall, there were 4,373 students across both start times who took the AIMS Reading assessment. The sample size within each group, later start time and earlier start time, were nearly identical, with 49.4% in the earlier time (n = 2161) and 50.6% in the later start time (n = 2212). Gender frequency among each school indicated a nearly 50/50 split, The SPED population for the Reading AIMS assessment represented 8.3% of the sample population, with a range from 6.1% up to 12% across schools. The majority of students were White (73%) and the remaining 27% were split among the four additional ethnic categories: 17% Hispanic, 3% Black, 5% Asian, and 1% Pacific Islander. There were variations among schools such that some had high populations of Hispanics or Whites as compared to others. The student sample from each high school varied across academic subjects: School 1 ranged from 20 % to 21%, School 2 range from 14% to 17%, School 3 ranged from 15% to 16%, School 4 range from 23% to 24% and School 5 ranged from 22% to 26%. Missing data was minimal, with gender being the only variable containing missing data (missing n = 9).

AIMS Mathematics Demographics. Overall, there were 4,318 students across both start times. The sample size within each group, later start time and earlier start time, were nearly identical, with 49.7 % in the earlier time (n = 2146) and 50.3% in the later start time (n =2172). Gender frequency also indicated a nearly 50/50 split between males and females across each school. The mean for the SPED population who took the Math AIMS assessment was 8.2%, with a range from 6% up to 11.8% across schools. The majority of students were White (73%) and the remaining 27% were split among the four additional ethnic categories: 17% Hispanic, 3% Black, 5% Asian, and 1% Pacific Islander. There were variations among schools such that some had high populations of Hispanic or White compared to others. Three of the five high schools each comprised 20-25% of the total student population while the remaining two schools were somewhat smaller, with 14-15% of the total sample from each school. Missing data was minimal, with gender being the only variable containing missing data (missing n =9).

AIMS Writing Demographics. Overall, there were 4,369 students across both start times. The sample size within each group, later start time and earlier start time, were nearly identical, with 49% in the earlier time (n = 2157) and 51% in the later start time (n = 2212). Gender frequency also indicated a nearly 50/50 split. The mean for the SPED population that took the Writing AIMS assessment was 8.2%, with a range from 6.1% up to 11.9% across schools. The majority of students were White (73%) and the remaining 27% were split among the four additional ethnic categories: 17% Hispanic, 3% Black, 5% Asian, and 1% Pacific Islander. Three of the five high schools had 20-25% of the student population while the remaining two schools were somewhat smaller, with 14-15% of the total sample from each school. Missing data was minimal, with gender being the only variable containing missing data (missing n = 9).

AIMS Science Demographics. Overall, there were 4,021 students across both school start times who took the AIMS Science assessment. The sample size within each group, later start time and earlier start time, were nearly identical, with 49% in the earlier time (n = 1955) and 51% in the later start time (n = 2066). Gender frequency also indicated a nearly 50/50 split across each school, as with other AIMS subjects. The mean for the SPED population that took the Science AIMS assessment was 7.9%, with a range from 5.2% up to 11.1% across schools. The majority of total students were White (72%) and the remaining 28% were split among the four additional ethnic categories: 17% Hispanic, 3% Black, 5% Asian, and 1% Pacific Islander. There were variations among schools such that some had high populations of Hispanic or White compared to others as demonstrated in the previous school demographic figures. Three of the five high schools each had 21-24% of the total student population while the remaining two schools were somewhat smaller, with 15-16% of the total sample from each school. Missing data was minimal, with gender being the only variable containing missing data (n =5).

Office Discipline Referral (ODR) participants. ODR data included high school students from all five high schools and all grade levels, 9^{th} through 12^{th} grade. The only student characteristic available in the ODR data aside from grade level was which school each student attended. Only students who received an ODR were available in the data set.

Type of ODR and time the offense occurred were also included in the data set. The 2009-2010 school year consisted of 8,840 students in the total population, with 2,027 students receiving 4,829 total ODRs. The following year, 2010-2011, there were 8,842 students, 2,149 of whom received a sum of 5,541 ODRs. Refer to Table 3 for descriptive statistics of the ODR data by student.

Measures

The present study utilized objective data from the school records at a local unified school district. The measures included: academic achievement and discipline data, each of which is described further in the following sections.

Academic Measures. The academic data collected included students' comprehensive standardized test scores primarily from the 10th grade cohorts.

Arizona Instrument to Measure Standards (AIMS). The AIMS is a federal and state- mandated, criterion and norm-referenced, standardized assessment that high school students, unless exempt for qualifying reasons, are required to pass in order to graduate (Arizona Department of Education, 2011). The high school AIMS assessment includes tests in the core subjects of reading, science, writing, and mathematics. This test is taken for the first time in high school when the student enters 10th grade, except for science (which includes 9th grade students) and once a student passes the required areas, he or she is no longer required to take the exams. Those who do not pass the first time are allowed up to four more attempts during 11th and 12th grade if needed (Arizona Department of Education, 2011).

Results from the AIMS for each student are categorized into one of four areas across each subject as indicated by the Arizona Department of Education (2011): Falls Far Below (FFB), Approaches (A), Meets (M), and Exceeds (E). A cutoff score is determined for each category using the students' scale scores. A student must score in the Meets or Exceeds range to pass the AIMS. The scaled scores can fluctuate over time, but for the 2009-2010 and 2010-2011 school years, the high school AIMS reading, math, and science scaled score ranges remained the same. For reading, the score ranges were: 500-626 (FFB), 627-673 (A), 674-772 (M), and 773-900 (E). In math, the ranges were: 300-470 (FFB), 471-486 (A), 487-536 (M), and 537-700 (E). In science, the ranges were: 200-474 (FFB), 475-499 (A), 500-536 (M), and 537-800 (E). For writing, however, the scale scores differed. The scores for 2010 range from 500 to 900 while in 2011 the scores range from 300 to 700. The score categories also changed. During the 2010 school year the ranges were: 500-609 (FFB), 610-677 (A), 678-753 (M), and 754-900 (E). In 2011, the scaled score for writing changed to the following ranges: 300-432 (FFB), 433-479 (A), 480-586 (M), and 587-700 (E).

The AIMS can undergo changes from year to year, thus the reliability and validity for both school years, 2009-2010, and 2010-2011, are reported from the technical reports published by the Arizona Department of Education (2010, 2011). Overall reliability and validity for the AIMS are good. For 2009-2010, the internal consistency was reported for multiple-choice tests and the reliability of hand scoring for all writing tests. For internal consistency, Cronbach's alpha ranged from .76 to .92 for reading and .87 to .95 for math across genders, ethnic groups, SPED, and English Language Learners (ELL). ELL students are determined in Arizona via Language surveys and the AZELLA placement test. The total alpha was .92 for reading and .95 for math. In science, the coefficients ranged from .70 to .93 across gender and ethnicity groups, with a total coefficient of .92. The inter-rater position consistency for the high school writing scoring resulted in interclass correlations of .68 to .72.

Differential Item Functioning (DIF) was calculated for ethnic groups and gender to identify items with potential bias. DIF statistics indicated that most items on the high school reading, math, and science assessments did not have a DIF or had weak DIFs. Only two math items had strong DIF- one against females and African Americans and one in favor of Asians. In reading, one item had strong DIF against females, and no science items had significant DIFs. Overall, correlations were high between tests measuring similar or the same constructs (e.g., norm-referenced math and criterion-referenced math) and correlations were much lower between dissimilar test constructs (e.g., math and writing).

For the 2010-2011 school year, reliability was also good, with internal consistency scores in reading ranging from .76 (ELLs) to .94 (Asian), with a .92 total. In math, the alphas ranged from .86 (ELLs) to .95 (Asian), with a .94 total. For science, the range was from .79 (ELLs) to .94 (Male and Asian), with a total of .93. The internal consistency for writing was .67 (ELLs) to .86 (Asian), with a .83 total. For science, the alphas ranged from .79 (ELLs) to .94 (Pacific Islander, Male, Asian). The inter-rater consistency for writing was .72 -.78.The DIF statistics for the 2010-2011 school year indicated only three items with strong DIF: two in math, one for and one against Asians, and one in reading against females.

Behavioral Measures. Discipline referrals are a common method of tracking a student's behavior in the school system. This type of behavioral measure will be utilized in the present study as indicators of school behavioral performance.

Office Discipline Referrals (ODRs). ODRs are given if a student is caught breaking a rule as specified in the district's code of conduct handbook. ODRs are used to track student behavior across the entire district and assist in determining appropriate behavior interventions for schools. The referrals can be reported by teachers or other school staff. There are several types of ODRs: attendance-related, drug-related, behavioral, and other. In the current study, ODRs from all categories were included in the overall analyses, and higher-frequency ODRS, including attendance-related and defiance and disrespect ODRs were analyzed separately. The attendance-related data included several individually-coded ODRs: truancy, tardy, leaving school grounds without permission, unexcused absence, and a category labeled other attendance issues. The second category of high-frequency ODRs consisted of defiance and disrespect referrals and disruption referrals.

Within the ODR data, the time of day was reported for each referral and this was used to determine which ODRs occurred during first period to address the related hypothesis. Several of the incidences were reported at times during which school was not in session. A variable was created in which the times reported were categorized as first period. First period was considered to be the first 45 minutes of school for each year since this is the approximate length of school periods; 7:45-8:30 A.M. for the earlier school start time and 8:15-9:00A.M. for the later school start time.

The ODR dataset contained a list of single ODRs, so they were grouped by student identification numbers such that each case in the dataset represented one student and how many overall ODRs they received and the number of: first-period ODRs, attendance-related ODRs, defiance/disrespect/disruption ODRs, and what school they attended of the five high schools included in the analysis.

Procedure

Once data was retrieved from the school records, data only for the participants described above was extracted and utilized. Data was derived and analyzed from two separate data systems, such that discipline referrals were in a separate data set from achievement data. One cohort included students from the earlier start time in 2010-2011 and the second included students from the later start time in the 2009-2010 academic year. Both academic and referral data were considered cross-sectional in the current study. Data was cleaned and organized to minimize missing data and better allow to for testing of the proposed hypotheses.

Chapter 4

Results

AIMS Achievement Hypotheses

The first four hypotheses proposed that students with later school start times would have higher academic achievement scores than those with earlier start times. In order to assess each academic area, four separate analyses were conducted with four separate data sets, one each for reading, math, science, and writing.

Analysis. The independent variable was the school start time and the dependent variables were AIMS scaled scores across subject areas. For reading, math and science AIMS, the scaled scores ranged from 300 to 700. For AIMS writing only, these scores were adjusted by converting to z-scores because the scale range changed from one year to the next (300 to 700 changed to 500 to 900).

Prior to conducting primary analyses, descriptive statistics were calculated, including the mean and standard deviation for each academic scaled score (Refer to Table 4). For the primary analysis, a one-way ANOVA was conducted for each AIMS subject to assess the mean differences in scores across school start times at a district-wide level (all five high schools). Five separate ANOVAs were also conducted to assess differences in scaled scores across start time at the individual school level (i.e., School 1, 2, 3, 4, 5) for each of the four AIMS subjects (i.e., Reading, Math, Science, Writing).

Assumptions. There are three main assumptions that underlie the use of ANOVA and affect interpretation of the results (Green & Salkind, 2008). These assumptions were considered prior to conducting the analyses for each AIMS academic subject.

Assumption 1: The first assumptions states that the variances of the dependent variable are normally distributed across the populations. The power of the ANOVA test would be reduced if the sample size was small or there were significant non-normal distributions. The current data consists of a large sample size and the distributions of the all achievement-related dependent variables are not significantly skewed, therefore the present data can be considered robust to this assumption.

Assumption 2: The second assumption is homogeneity of variances, which requires that the error variances be equal across groups. In order to test this assumption, Levene's test of equality of error variances was used for each AIMS data set (i.e., Reading, Writing, Math, and Science). The null hypothesis of Levene's test is that the error variances of the dependent variable are equal across groups. This hypothesis was accepted for math and writing, but rejected for reading and science. However, given that the Levene's test is an inferential statistic that is influenced, in part, by sample size, it is reasonable to assume that the significant Levene's test was due to the present study's large sample size rather than significant differences between the error variances. The large sample size again minimizes the effects of a heterogeneity of variances as well.

Assumption 3: The third assumption states that the cases represent random samples and the scores are independent of each other. In this study, the AIMS scores in each group are independent from each other because they are not from same student/person, however, the sample is a convenience sample, not random. The district could not be randomly selected because only certain districts changed their school start time. Thus, the present analyses were conducted with the understanding of the limitations of interpretation when using a non-random sample.

Missing Data. After combining ethnic categories as described earlier, there was no missing ethnic information for students with AIMS data. Any student who did not have a scaled score reported was removed from the data set prior to conducting any analyses or descriptive statistics. In the 2009-2010 school year, there were a total of nine students who were not included because the scaled score was missing for AIMS Writing. In 2010-2011, five students were removed with missing scaled scores, three from AIMS Writing and two from AIMS Math. Students with a missing gender category were also deleted using list-wise deletion during the ANOVA analysis, meaning they were not removed from the data set completely, but were not included in the primary analyses. All other AIMS data were complete.

Reading Achievement Results. The first achievement-related hypotheses posited that students who attended high school during the later school star time would have higher achievement on the Reading AIMS test compared to those attending during the earlier start time. A one-way between-subjects ANOVA was conducted at the district-wide level (all five high schools) to determine the relationship between reading scores and school start time. The ANOVA was not significant, $F(1, 4372)$, $= 0.24$, $p = 0.63$. School start time accounted for none of the variance of AIMS reading scores.

Following the district-level analysis, analyses were conducted at the individual school level since there appeared to be some differences between schools related to ethnicity and SES. A one-way between-subjects ANOVA was conducted for each school with the reading scaled score as the dependent variable and start time as the independent variable. The ANOVAs were not significant for any of the five schools. School One's results were $F(1, 903)$, $= 2.57$, $p = 0.11$. Within School Two, the ANOVA was also non-significant, $F(1, 626)$, $= 0.85$, $p = 0.36$. An ANOVA for School Three was not significant, $F(1, 691)$, $= 0.01$, $p = 0.94$. The ANOVA for School Four was not-significant, $F(1, 1032)$, $= 0.54$, $p = 0.46$. Finally, the ANOVA was not significant for School Five, $F(1, 1116)$, $= 0.14$, $p = 0.71$. The variance accounted for by school start time on AIMS Reading Scores within each school was less than 1%. No follow-up tests were conducted because no statistically significant results were found for AIMS Reading at the district-wide or school-wide levels. The results of the AIMS Reading ANOVAS are displayed in Table 5.

Math Achievement Results. The second achievement-related hypotheses posited that students attending high school during the later school start time would have higher achievement on the Math AIMS test compared to those attending during the earlier start time. A one-way between-subjects ANOVA was conducted at the district-wide level (all five high schools) to determine the relationship between math scores and school start time. The ANOVA was not significant, $F(1, 4317)$, $= 1.07$, $p = 0.30$. School start time accounted for none of the variance of AIMS math scores.

Following the district-level analysis, individual schools were analyzed for differences in AIMS math scores. A one-way between-subjects ANOVA was conducted for each school with the math scaled score as the dependent variable and start time as the independent variable. None of the ANOVAs at the individual school level were significant. The ANOVA was not significant for School One, F (1, 899), = 1.73, p = 0.19. Within School Two, the ANOVA was also non-significant, F (1, 609), = 2.88, p = 0.09. An ANOVA for School Three was not significant, F (1, 670), = 1.30, p = 0.26. The ANOVA for School Four was not-significant, F (1, 1027), = 2.73, p = 0.10. Finally, the ANOVA was not significant for School Five, F (1, 1108), = 0.06, p = 0.81. Less than 1% of the AIMS Math scores variance was accounted for by start time within each of the schools. No follow-up tests were conducted because no statistically significant results were found for AIMS Reading at the district-wide or school-wide levels. The results of the AIMS Math ANOVAS are displayed in Table 6.

Writing Achievement Results. The third hypothesis posited that students with a later school start time would perform better on the AIMS Writing assessment compared to students with an earlier school start time. After adjusting the scaled scores to z-scores, a one-way between-subjects ANOVA was conducted at the district-wide level (all five high schools) to determine the relationship between science scores and school start time. The ANOVA was not significant, F (1, 4368), = 0.00, p = 1.00. School start time accounted for none of the variance of AIMS writing scores.

Following the district-level analysis, individual schools were analyzed for differences in AIMS writing scores. A one-way between-subjects ANOVA was conducted for each school with the writing scaled score as the dependent variable and start time as the independent variable. Four of the five schools did not exhibit significant differences across star time. The ANOVA was not significant for School One, F (1, 907), = 0.16, p =0.69. Within School Two, the ANOVA was also non-significant, F (1, 623), =

0.26, p = 0.61. The ANOVA for School Four was not-significant, F (1, 1028), = 0.12, p = 0.73. Finally, the ANOVA was not significant for School Five, F (1, 1118), = 1.66, p = 0.20. However, the ANOVA for School Three was significant, F (1, 688), = 7.282, p = 0.01. Partial eta squared indicated that 1% of the variance was accounted for by school start time at this school. Upon further examination of the estimated marginal means, the mean of the later start time was 0.07 and the earlier time was -0.16, which indicates lower Writing scaled scores during the earlier school star time. The results of the AIMS Writing ANOVAS are displayed in Table 7.

Science Achievement Results. The fourth hypothesis of the current study posited that students attending school during the later school start time would have higher achievement scores on the AIMS Science assessment as compared to students in the earlier school start time. A one-way between-subjects ANOVA was conducted at the district-wide level (all give high schools) to determine the relationship between science scores and school start time. The ANOVA was not significant, F (1, 1), = 2.54, p = 0.11. School start time accounted for none of the variance of AIMS science scores.

Following the district-level analysis, individual schools were analyzed for differences in AIMS science scores. A one-way between-subjects ANOVA was conducted for each school with the science scaled score as the dependent variable and start time as the independent variable. The ANOVA was not significant for School One, F (1, 1), = 1.02, p = 0.31. Within School Two, the ANOVA was also non-significant, F (1, 1), = 2.77, p = 0.10. An ANOVA for School Three was not significant, F (1, 1), = 2.20, p = 0.14. The ANOVA for School Four was not-significant, F (1, 1), = 0.16, p =

0.69. Finally, the ANOVA was not significant for School Five, F (1, 1), = 0.80, p = 0.37. Less than 1% of the variance of AIMS Science scores were accounted for by school start time within each school. No follow-up tests were conducted because no statistically significant results were found for AIMS Science at the district-wide or school-wide levels. The results of the AIMS Reading ANOVAS are displayed in Table 8.

Follow-up AIMS Analysis

The AIMS scaled scores were also categorized by performance using the cutoff scores described earlier to place students in the following levels: Falls Far Below (Fail), Approaches (Fail), Meets (Pass), and Exceeds (Pass). If a student's scaled score falls within the Falls Far below or Approaches range, they are required to retake and attempt the assessment. Because these categories are ordinal, the hypothesis was evaluated using a non-parametric test, the Mann-Whitney, which evaluates the difference between medians rather than means. Table 9 displays the results of follow-up analysis for each AIMS subject utilizing this categorical scale to compare differences in performance across school start times beyond scaled scores to determine if the hypothesis that students attending the earlier school start time would have lower academic performance.

Similar to the primary analysis results, the Mann-Whitney calculated for AIMS reading performance by category did not significantly differ, z = -1.65, p = 0.10, meaning the percentage of students within each category were approximately the same during both school years.

Math AIMS scores, did have groups that significantly differed across years, z = -2.22, p = 0.03, so post-hoc analysis was conducted to determine which categories were significantly different. There was no significant difference between the two categories that represent students that passed and the two that represent students that failed according to the Mann-Whitney Test (z = -0.05; p = 0.96). However, a significant difference was found between the two groups with regards to the number of students who were Meets and Exceeds. More students Exceeded in math in the later start time (n = 42%) compared to the earlier start time (37%), with a significance of z = -3.52, $p < 0.01$. Although statistically significant, the overall estimated effect size, when examining the medians of the two school start time groups, was relatively small. The median was 3.0 (Meets) in both groups.

The AIMS Writing performance categories were also statistically significantly different when conducting a Mann-Whitney to examine differences in pass/fail categories across start times (z = -10.22, $p < 0.01$). Further analysis indicated that a significant difference existed between the pass and fail categories, z = -3.22, $p < 0.01$, such that more students failed in the earlier start time compared to the later start time. The effect size as estimated by the median score of each year was relatively small because the median did not change (2.0 in both start time groups).

The difference between categories of performance across start times were also examined for AIMS Science. A significant difference was found across the four categories (z = -2.04, p = 0.04). However, the median score was 3.0 (Meets) for both start time groups, indicating a minimal effect size and the difference between the fail and pass categories was non-significant (z = -1.79, p = 0.07).

Office Discipline Referrals (ODRs)

The last four hypotheses proposed that there would be fewer ODRs reported (Hypothesis 5), less ODRs during first period (Hypothesis 6), fewer attendance-related ODRs (Hypothesis 7), and fewer defiance, disruption and disrespect ODRs (Hypothesis 8), during the later school start time compared to the earlier school start time.

Analysis. ODR data was examined via descriptive statistics and statistical analyses and described below. First, descriptive statistics were calculated for each ODR independent variable across the students who received them. When comparing the frequency of all categories of ODRs, there was a 16.6% increase in number of referrals during the earlier start time (n = 4829 for later time, n = 5541 for earlier time). Table 10 displays the number of students, mean, standard deviation and skewness of each variable across start times.

An ANOVA was used to assess the proposed hypotheses using ratio-level continuous ODR variables. According to the descriptive statistics, the distribution of the ODRs across start times indicated positively skewed data and unequal variances. This information was used in considering the robustness of the data with regards to the assumptions of ANOVA.

Assumptions. The following assumptions specific to ANOVA are addressed below as described by Green and Salkind (2008):

Assumption 1: The first assumptions states that the variances of the dependent variable is normally distributed across the populations. Larger samples sizes are usually robust to this assumption, and can generally produce accurate p-values when that is the case. In the current study, the ODR was positively skewed when examining the histograms of the data across start times and within each school, but the sample size is large.

Assumption 2: The second assumption is homogeneity of variances, which requires that the error variances be equal across groups. In the current sample, the variances differ across start times and even more so within schools across the dependent variables. The Welch statistic was used to calculate the p-values for the ANOVAs because this assumption has been violated and the Welch statistic does not assume equal variances across groups (Green & Salkind, 2008) and can reduce the power to detect a significant difference, however, the current sample already has relatively high power because of the substantial sample size.

Assumption 3: The third assumption states that the cases represent random samples and the scores are independent of each other. The ODRs are a convenience sample that represents the entire population of students who received ODRs during each start time across the five high schools. The data is cross-sectional in that the students are not matched and are not being directly compared to one another. Some of the students within each start time group are the same, however they still represent a total sample from two different school years.

Missing Data. Some ODR data did not have an ODR category type specified, but they could still be included in the total referral counts for each student. None of the other variables had missing data.

Hypotheses Results. An ANOVA was conducted to examine the significance of the overall ODRs, first-period ODRs, defiance/disruption/disrespect ODRs, and attendance-related ODRs. The Welch statistic indicated statistically significant results for all of the hypotheses as displayed in Table 11, showing that there were significant differences with regards to the number of ODRs students who had been referred received in the later versus earlier start time. Overall ODRs was significant ($p = 0.01$) and the specific types of ODRs examined (attendance, first period, disruptive referrals) were all statistically significant, $p < 0.01$. The mean increases for students with ODRs across school years were all positive, but the actual change in each mean was relatively small. The mean for ODRs increased from 2.38 to 2.58. The mean for first-period ODRs increased from 0.37 to 0.53. The mean for defiance/disruption/disrespect referrals increased from 0.42 to 0.59. The mean for attendance-related referrals increased from 0.82 to 1.09.

To determine practical significance, the eta square ($\eta 2$) statistics were calculated. According to Green and Salkind (2008), eta square (also reported as partial-eta squared) of .01, .06, and .14 are considered small, medium and large effect sizes. The effect sizes were: $\eta 2 = .002$ for overall ODRs, $\eta 2 = .006$ for defiance/disrespect and disruption ODRs, $\eta 2 = .01$ for attendance-related ODRs, and $\eta 2 = .008$ for first-period ODRs. In other words, the proportion of variance of these variables that are related to start time is quite small (1% or less), with attendance accounting for the highest proportion of variance among the dependent variables.

Changes in the total population were also considered by examining percentage changes of students with ODRs relative to the general student populations in the high schools. There were 2027 students with at least one referral in 2009-2010 and 2149 students with referrals in 2010-2011. This equates to 23% students in the total school populations received ODRs in the 2009-2010 school year and 24% in the 2010-2011 school year. The change in percentage of students who received ODRs within each school varied as shown in Table 12, with some schools increasing in the percentage of students receiving ODRs and others decreasing.

Chapter 5

Conclusions and Recommendations

The importance of sleep for optimal human functioning, especially during adolescence, is apparent in the literature (Carskadon, 1990; Dement & Vaughn, 1999). Sleep is essential to the entire human species, and while the amount of sleep remains similar across late childhood and adolescence, insufficient sleep during the teen years is a national issue (Crabtree & Williams, 2009; Liu et al., 2005; NSF, 2006). The biological mechanisms that affect sleep, including the circadian rhythm and biological clock, adjust the sleep cycle such that adolescents generally fall asleep later and wake up later than do younger children (Crowley et al., 2007; Dahl & Lewin, 2002).

There are also several social and environmental factors that play a role in the amount and quality of sleep adolescents receive, and the one of interest in the current study is school start time. Nearly all adolescents attend high school in the United States, and most of them begin classes earlier than elementary schools. Although few in number, there are studies that have begun to link the school start time and its effects on academic and behavioral performance at school via the notion that students getting up earlier for school are getting less sleep (Wahlstrom, 1998, 2001). Studies have shown that later start times result in more sleep for adolescents during the early morning time (e.g., Kowalski & Allen, 1995) because adolescents tend to go to bed at the same time regardless of start time (Carskadon et al., 1998). The extra sleep these students receive has been correlated with better school performance (Drake et al., 2003).

Given the literature linking sleep with school start time and school performance, the present study hypothesized that students who began school later each day would have better academic performance and fewer discipline referrals and attendance issues compared to students with a start time thirty minutes earlier. Utilizing data from a standardized achievement assessment administered to high school students across five schools within the same district, it was found that overall, there were no significant differences in performance in any of the four academic areas measured by scaled scores when comparing students from the earlier and later school start times. The overall findings of the primary analysis utilizing students' scaled scores did not support the evidence in the literature that students with a later start time would have better academic achievement. Additional ANOVAs conducted for each school within each academic area indicated non-significant results as well, except for Writing AIMS scaled scores for School 3. There was a significant mean decrease in the scaled score, meaning the relationship was significant, but the effect size overall was small.

Follow-up nonparametric analysis of categorically-organized academic performance outcomes (i.e., Falls Far Below, Approaches, Meets, Exceeds) revealed some statistically significant results that were not detected when examining scaled scores. In reading, there remained no difference between the two start time groups. In math, the initial non-parametric test across the four levels was significant. Follow-up analysis comparing fail (Falls Far Below, Approaches) versus pass categories (Meets, Exceeds) was not significant, but there was a significant difference between the number of students that were Meets versus Exceeds on the AIMS Math. In other words, students passed at a higher level in the later start time than the earlier start time. In science, there were significantly more students who passed compared to those who failed in the earlier time. In writing, there were also more students that failed compared to the later start time, however the effect sizes were minimal for both subjects.

The overall results indicate possible small effects of changing the school start time on AIMS achievement, but this change is not consistent across subjects and is not detected by scaled scores at the district-wide level. The changes in performance when examined by category may be more beneficial for districts than scaled score differences and this is where more significant differences were found. School movement towards proficiency is measured using these AIMS categories in Arizona. Reading was not affected across the board, but there were differences in the other subjects (Math, Writing, and Science) which may suggest these subjects are more affected by environmental or system changes than reading. The subject matter also compounds in these three subjects, meaning that new concepts are introduced, whereas reading may more stable over time. For this reason, less change would then be detected in a student's reading performance.

The second set of hypothesis in the current study required analysis of ODR data available across all five high schools. When conducting statistical analyses to examine the differences in students who received ODRs each year, there was a statistically significant difference between the two school start times with regards to overall ODRs, first-period ODRs, attendance-related ODRs, and defiance/disruption/disrespect ODRs. The effect sizes were small, with attendance-related ODRs accounting for the largest amount of variance (about 1%), indicating some level of support for the hypothesis that more students in the earlier start times would receive ODRs related to attendance. One explanation for the contrast between statistical and practical significance found is that the overall sample size was so large that even the smallest differences were able to be detected because of the power of the sample. Also, there are differences in the high schools themselves that will be discussed more in the follow section that may affect the ability to detect significant effect sizes in the overall student population.

Strengths and Limitations of the Analysis

As with all empirical studies, strengths and limitations are considered which may have affected the results of the present study. The data utilized for testing each hypothesis was quantitative and more objective than self-report data. The district involved also included a varied population with regards to ethnicity and socioeconomic status. Given the results of previous studies, it was also assumed that most students during the later start time were getting more sleep, thus the basis for the proposed hypotheses. One limitation is the archival nature of the data. Information could not be gathered to confirm that students attending school during the later time actually slept more than students during the earlier time.

With regards to academic achievement, missing data was minimal, and although a few cases had unclear ethnic data, steps were taken in attempt to maximize the sample size, while excluding cases with scaled scores that were zero or missing. Another strength of the AIMS data is that availability of quantitative data that provides students' scaled scores in addition to what category that places them into with regards to passing or failing. Students who took the AIMS tests after 10th grade were also excluded as there was no way to determine if it was their first attempt or if they had failed a previous attempt. It is possible that this exclusion may have restricted the range of academic performance on the AIMS. However, the focus of the present study was to examine students who were taking the AIMS for the first time each year as including other students that may be on their second or third attempt may have confound the findings.

One limitation is that the AIMS scores are from one specific test given near the end of the school year and may not be representative of the student’s daily performance in school. In other words, a student may test well, but this score does not take into account other academic factors that may be more affected by a change in start time, such as grades, or homework completion. The AIMS test also covers material learned in previous school years and is an accumulation measure of knowledge. The test is also taken over one period of several days. It gives a minimum level of competency in an entire subject whereas the differences in amount of sleep inferred by the change in school start time may be more likely to affect grades within the classes that are reflective of material learned and presented during that specific time period. However, it is a more objective measure of ability than self-reports of GPA and actual GPAs. GPAs are determined from grades in individual classes, which leads to a great deal of variation in how each student’s GPA is determined. Another limitation is the inability to compare over a longer period of time, which perhaps may have resulted in more noticeable differences. The present data included large sample sizes, and the data was cross-sectional so it did not allow comparison for the same students across years. Despite these limitations, there were significant findings when examining categorized performance data, which as mentioned earlier, may be a more useful way to examine and apply the results of standardized assessment data because of the value schools hold on their overall performance.

The data related to ODRs also provided a large sample size and an objective measure of referrals, to the degree that whether or not a referral is given may be subjective. For instance, it is up to the discretion of teachers and staff at each school whether or not they issue a referral to a student. Thus, there may be other referral-worthy behaviors that go un-reported and it is then difficult to discern the accuracy of the total numbers. A strength of the ODR data is that all referrals were examined from all five high schools, which provide a diverse population that may be representative of other schools or districts in the nation.

Differences across schools is one possible reason why the results of the referral data across the entire district was not practically significant. For instance, some teachers may be more lenient with students who are regularly performing a misconduct that should earn a referral while other staff or teachers may be more stringent and report referrals more frequently. Although there were some within school differences across start times, it is unclear why some schools experienced more changes in students referred than others. There may be factors such as changes in the reporting of referrals such as new types of referrals or new staff or administration that view the importance of specific behaviors differently. There were also varying sample sizes with regards to the number of students who received referrals, and some schools had significant differences between start times while others did not. One interesting observation between the ODR and

AIMS data is that School Three was the only school to demonstrate significant differences in scaled scores (for Writing only) and was also the school with the biggest increase in the number of students who received at least one referral (7% increase between school start time groups). The school characteristics that are known about this particular school do not indicate any particular difference between gender, SES, changes in administration, or ethnicity compared to the other schools, but there may have been another unknown change that occurred in this school that may have impacted their performance.

A second limitation is that the ODR data contained only students with referrals and therefore a comparison to students not referred was not conducted. With the present data, conclusions can only be drawn about students who receive at least one discipline referral. This information is useful in determining potential increases in referrals at a school or district level, but it does not provide information regarding increased likelihood of any particular student's potentially increased risk of receiving a referral. However, when making changes at a school or district level, it is important to consider the overall change in referrals as was done in the present study. Thus, having both sets or types of data would be ideal to examine changes at both individual student and a more general level.

Implications for Future Research and Practical Applications

The present study intended to underscore the importance of school start time, its relation to sleep, and the effects of school start time on academic and school behavior. This research is a stepping stone towards utilizing more objective and quantitative data collected by school systems rather than self-reported grades to examine the effects of start time on their students' performance. The available data which can be used to analyze the effects of school start times is currently limited in quality and quantity, but it still allows for a better idea of what further data needs to be collected.

By gaining a better understanding of such effects, the hope is that school policy is informed by research and objective information will be taken into consideration when determining methods of improving student performance. While most schools appear to be resistant to such changes (Lamberg, 2009), if the research persists and builds, there is increased likelihood that society's persistent focus on increasing school achievement will lead to more acceptance of taking adolescent sleep patterns into considering school start times.

It would be ideal for future research to examine multiple academic and behavioral measures. As previously mentioned, using student grades in first period academic classes (students with P.E. or other specials may not be useful to include) or examining longitudinal changes may be more informative for what specific academic areas or behaviors may be more affected. However, as noted in previous studies, it is difficult to calculate differences statistically between student grades, for reasons such as honors classes that have weighted grade, which can also be more subjective than standardized assessments. GPAs would be another option of measuring academic achievement, but again, calculating differences can be difficult and in order to be more objective, GPAs would have to be obtained directly from the school rather than self-reported. There are also differences between districts in grading policies and curriculum that would make it difficult to generalize any results found. Perhaps if a district were to pursue changes in school start time, it would be beneficial to set up standardized pre- and post- tests for students specially designed to measure changes in students' achievement. Furthermore, parsing out students attending honors or APA classes as the current study had done with students enrolled in Special Education may also allow for a more objective analysis that rules out more factors unrelated to start time that may be affecting the outcomes of the analysis when trying to determine differences. For instance, it may be useful to look at differences within these difference populations- general education only, SPED enrolled, and APA/Honors course-enrolled students. Future research examining changes in behaviors across schools, would also benefit from including all students within the population (e.g., students who did and did not earn referrals) as a means of tracking individual changes for each student.

The results from the ODR data of the current study indicated that school start time likely does affect general attendance problems, such that schools are likely to have more attendance issues with an earlier start time compared to a later time. However, the effect size found in the present study was small and the availability of actual attendance data for students across different start times would have allowed for more objective measurement of the change in student behavior. Total attendance data for each school by year was unavailable for use in the present study. Future studies would help solidify this finding. Recommendations for further examination of referrals and discipline would include analyses at the school level and gathering data regarding the school community characteristics (e.g., average income, ethnicity) to provide a better understanding of why schools differ in the type and number of referrals they have.

In addition, previous studies have shown some correlation with sleep/start time and social-emotional functioning. Future studies may implement social emotional questionnaires to all students in multiple schools or across multiple years to examine specific sleep habits in students at schools which have experienced changes in school start times. For example, the Sleep Disorders Inventory for Students (SDIS; Marsha Luginbuehl, 2003) could be administered to students as a more object measure that is comparable across students. Such research could assist in the application of current literature indicating correlations between social-emotional difficulties and less sleep to the changes in school start time.

Other behavioral aspects that could be observed or measured also include technology use as research has begun to make connections between its use and sleep (Van den Bulck, 2007). These and other upcoming technologies can help expand what we know about sleep, particularly the sleep change that is occurring during adolescence and how it affects cognitive and behavioral functioning. To record such information, a check-in system could be implemented with students so that they post what time they go to sleep and awake each day.

A final suggestion for future research stems from another potential limitation of the current study, which is that the difference in school start times was only 30 minutes and greater effects might have been noted if the start times were more discrepant. Furthermore, it may not be amount of delay that needs to become more discrepant, as some schools may have slightly later start times already, but it may be a matter of determining the best overall time for high schools to start given the natural sleep cycles. For example, in the Minnesota study, schools not only were delayed for 30 minutes, but the start time was 9:10 A.M. This could be assisted by more experimental research examining the natural wake times of adolescents across the nation. If the benefits of the additional sleep can be documented in the literature and a more specific wake time can be generalized, the combined efforts may lead to a better school structure for adolescents such that they can attend school at periods of the day at which they can optimally function cognitively and behaviorally.

References

Acebo, C., & Carskadon, M. A. (2002). Influence of irregular sleep patterns on waking behavior. In M. A. Carskadon (Ed.), *Adolescent sleep patterns: Biological, social, and psychological influences* (pp. 220–235). Cambridge, UK: Cambridge University Press.

Adams, D. & Sheslow, W. (1990). *Wide Range Assessment of Memory and Learning: Manual.* San Antonio: The Psychological Corporation, Harcourt Brace & Co.

Andraded, M. M., Benedito-Silva, A. A., Domenice, E. E. S., Arnold, I. J. P., & Menna-Barreto, L. M. (1993). Sleep characteristics of adolescents: A longitudinal study. *Journal of Adolescent Health, 14,* 401-406.

Arizona Department of Education. (2011). 2011 Arizona technical report. Retrieved from http://www.azed.gov/standards-developmentassessment/files/2011/12/AIMS_tech_report_2011_final.pdf.

Arizona Department of Education. (2010). 2010 Arizona technical report. http://www.azed.gov/standards-development-assessment/files/2011/12/AIMStechreport2010.pdf

Aserinsky, E., & Kleitman, N. (1953). Regularly occurring periods of eye motility and concomitant phenomenon during sleep. *Science, 118,* 273-274.

Ax, E.E., Shaffer, E., & Bradley-Klug, K.L. (2007). *Effect of Symptoms of Sleep Problems on School Behavior, Academics and Quality of Life.* Paper accepted at the meeting of the International Society for Quality-of-Life Studies (ISQOLS), San Diego, CA.

Boll, T. (1993). *Children's Category Test: Manual*. San Antonio: The Psychological Corporation, Harcourt Brace & Co.

Borberly, A. A. (1982). A two process model of sleep regulation. *Human Neurobiology, 1,* 195-204.

Burgess, H. J. & Eastman, C. I. (2004). Early versus late bedtimes phase shift the human dim light melatonin rhythm despite a fixed morning lights on time. *Neuroscience Letters, 356,* 115-118.

Cain, N., Gradisar, M., & Moseley, L., (2011). A motivational school-based intervention for adolescent sleep problems. *Sleep Medicine, 12,* 246-251.

Carskadon, M. A. (2011). Sleep in adolescents: The perfect storm. *Pediatric Clinics North America*, *58,*637-647. doi: 10.1016/j.pcl.2011.03.003

Carskadon, M. A. (1999). When worlds collide: Adolescent need for sleep versus societal demands. *The Phi Delta Kappa, 80,* 384-353.

Carskadon M. A. (1990). Patterns of sleep and sleepiness in adolescents. *Pediatrician, 17,* 5–12.

Carskadon, M. A. *Determinants of Daytime Sleepiness: Adolescent Development, Extended and Restricted Nocturnal Sleep.* Dissertation submitted to Stanford University in partial fulfillment of the requirements for the degree of doctor of philosophy, 1979.

Carskadon, M. A., & Acebo, C. (1997). Historical view of high school start time: preliminary results. *Sleep, 26,* 184.

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

Carskadon, M. A., Acebo, C., Richardson, G. S., Tate, B. A., & Siefer, R. (1997). An approach to studying circadian rhythms of adolescent humans. *Journal of Biological Rhythms, 12,* 278-289. doi: 10.1177/07487304901200309

Carskadon, M. A., & Dement, W. C. (1979). Effects of total sleep loss on sleep tendency. *Perceptual and Motor Skills, 48,* 495-506.

Carskadon, M. A., & Dement, W. C. (1977). Sleepiness and sleep state on a 90-minute schedule. *Psychophysics, 14,* 127-133.

Carskadon, M. A., Harvey, K., & Dement, W. C. (1981). Sleep loss in young adolescents. *Sleep, 4,* 299-312.

Carskadon, M., Harvey, K., Duke, P., Anders, T., Litt, I., & Dement, W. (1980). Pubertal changes in daytime sleepiness. *Sleep, 2,* 453-460.

Carskadon, M. A., Seifer, R., & Acebo, C. (1991). Reliability of six scales in a sleep questionnaire for adolescents. *Sleep Research*, 20, 421.

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

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

Cassoff, J., Knauper, B., Michaelsen, S., & Gruber, R. (2012). School-based sleep promotion programs: Effectiveness, feasibility, and insights for future research. *Sleep Medicine Reviews.* Retrieved from: http://dx.doi.org/10.1016/j.smrv.2012.07.001

Colrain, I. M., & Baker, F. C. (2011). Changes in sleep as a function of adolescent development. *Neuropsychology Review, 21*, 5-21. doi: 10.1007/s11065-010-9155-5

Crabtree, V. M., & Williams, N. A. (2009). Normal sleep in children and adolescents. *Child Adolescent Psychiatric Clinic North America, 18,* 799-811. doi: 10.1016/j.chc.2009.04.013

Crowley, S. J., Acebo, C., & Carskadon, M. A. (2007). Sleep, circadian rhythms, and delayed phase in adolescence. *Sleep Medicine, 8,* 602-612. doi: 10.1016/j.sleep.2006.12.002

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

Delis, D., Kramer, J., Kaplan, E., & Ober, B. (1994). California Verbal Learning Test-Children’s Version: Manual. San Antonio: The Psychological Corporation, Harcourt & Brace Co.

Dement, W. C. (1993). Sleepiness. In *Encyclopedia of Sleep and Dreaming. (*Vol. 1, p. 554). New York, NY: Macmillan Publishing Company.

Dement, W. C., & Vaughn, C. (1999). *The promise of sleep.* New York: Dell Publishing.

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

Diekelmann, S. Wilhelm, I., & Born, J. (2009). The whats and whens of sleep-dependent memory consolidation. *Sleep Medicine Reviews, 13,* 309-321.

Dornbusch, S. M. (2002). Sleep and adolescence: A social psychologist's perspective. In: Carskadon M (ed.) *Adolescent Sleep Patterns: Biological, Sociological, and Psychological Influences,* Cambridge, United Kingdom: Cambridge University Press.

Drake, C., Nickel, C., Burduvali, E., Roth, T., Jefferson, C., & Pietro, B. (2003). The pediatric daytime sleepiness scale (PDSS): sleep habits and school outcomes in middle-school children. *Sleep, 26*, 455–458.

Eaton, D. K., McKnight-Eily, L. R., Lowry, R., Perry, G. S., Presley-Cantrell, L., Croft, J. B. (2010). Prevalence of insufficient, borderline, and optimal hours of sleep among high school students- United States, 2007. *Journal of Adolescent Health, 46,* 399-401.

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

Eliasson, A., Eliasson, A., King, J., Gould, B., & Eliasson, A. (2002). Association of sleep and academic performance. *Sleep and Breathing, 6*, 45-48.

Epstein, R., Chillag, N. & Lavie, P. (1998). Starting times of school: effects on daytime functioning of fifth-grade children in Israel. *Sleep, 21,* 250-256.

Fallone, G., Owens, J. A., & Deane, J. (2002). Sleepiness in children and adolescents: clinical implications. *Sleep Med Rev, 6,* 287-306.

Fuligni, A. J., & Hardway, C., (2006). Daily variation in adolescents' sleep, activities, and psychological well-being. *Journal of Research on Adolescence, 16,* 353-378.

Gangwisch, J. E., Babiss, L. A., Malaspina, D., Turner, J. B., Zammit, G. K., & Posner, K. (2010). Earlier parental set bedtimes as a protective factor against depression and suicidal ideation. *Sleep, 33,* 97–106.

Gradisar M., Lack L., Richards H., Harris, J., Gallasch, J, Boundy, M., & Johnston, A. (2007). The Flinders Fatigue Scale: Preliminary psychometric properties and clinical sensitivity of a new scale for measuring daytime fatigue associated with insomnia. *Journal of Clinical Sleep Medicine, 3,* 722-728.

Gradisar, M., Terrill, G., Johnston, A., & Douglas, P. (2008). Adolescent sleep and working memory performance. *Sleep and Biological Rhythms, 6,* 1460154.

Gray, E. K., & Watson, D. (2002). General and specific traits of personality and their relation to sleep and academic performance. *Journal of Personality, 70*, 177–206.

Hagenauer, M. H., Perryman, J. I., Lee, T. M., & Carskadon, M. A., (2009). Adolescent changes in the hu8juomeostatic and circadian regulation of sleep. *Developmental Neuroscience, 31,* 276-284.

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

Harsh, J. R., Easley, A., & LeBourgeois, M. K. (2002). A measure of children's sleep hygiene. *Sleep,* 25 (Suppl.), A316–A317.

Hauri, P. (1993). Alpha-delta sleep. In *Encyclopedia of Sleep and Dreaming. (*Vol. 1, p. 27). New York: Macmillan Publishing Company.

Heaton, R. (1981). *Wisconsin Card Sorting Test: Manual.* Odessa, FL: Psychological Corporation, Harcourt & Brace Co.

Hofman, W. F., Steenhof L. (1997). Sleep characteristics of Dutch adolescents are related to school performance. *Sleep-Wake Research in the Netherlands, 8,* 51-55.

Jenni, O., G., & Carskadon, M., A., (2004). Spectral analysis of the sleep electroencephalogram during adolescence. *Sleep, 27,* 774–783.

Jenni, O. G., Achermann, P., & Carskadon, M. A. (2004). Evidence for maturational changes in process S during adolescence based on empirical data and simulations. *Sleep, 27,* A111.

Jenni, O. G. & O'Connor, B. B. (2005). Children's sleep: an interplay between culture and biology. *Pediatrics, 115,* 204–216.

Jenni, O. G., Van Reen, E. and Carskadon, M. A. (2005). Regional differences of the sleep electroencephalogram in adolescents. *Journal of Sleep Research, 14*: 141–148.

Jin, Q., & Shi, Q. (2008). A comparison of the number of hours of sleep in high school students who took advanced placement and/or college courses and those who did not. Journal of School Nursing, 24, 417-424. doi: 10.1177/1059840508326747

Kelly, W. E., Kelly, K. E., & Clanton, R. C. (2001). The relationship between sleep length and grade point average among college students. *College Studies Journal, 35,* 84–86.

Kirby, M., Maggi, S., & D'Angiulli, A. (2011). School start times and sleep-wake cycle of adolescents: A review and critical evaluation of available evidence. *Educational Researcher, 40,* 56-61.

Kleitman, N. (1993) Basic rest-activity cycle. In *Encyclopedia of Sleep and Dreaming. (*Vol. 1, pp. 65-66). New York, NY: Macmillan Publishing Company.

Kowalski, N.A. & Allen, R.P. (1995). School sleep lag is less but persists with a very late starting high school. *Sleep Research 24*: 124.

Laberge, L., Petit, D., Simard, C., Vitaro, F., Tremblay, R. E. & Montplaisir, J. (2001). Development of sleep patterns in early adolescence. *Journal of Sleep Research, 10,* 59–67.

Lamberg, L. (2009). High schools find later start time helps students' health and performance. Journal of the American Medical Association, 301, 2200-2201.

Lima, S. L., Rattenborg, N. C., Lesku, J. A., & Amlaner, C. J. (2005). Sleeping under the risk of predation. *Animal Behaviour*, *70,* 723-736.

Liu, X., Liu, L., Owens, J. A., & Kaplan, D. L. (2005). Sleep patterns and sleep problems among schoolchildren in the United States and China. *Pediatrics, 115,* 241–249.

Manni, R., Ratti, M. T., Marchioni, G., Castelnovo, G., Murelli, R., Sartori, C., . . . Tartara, A. (1997). Poor sleep in adolescents: A study of 869 17-year old Italian secondary school students. *Journal of Sleep Research, 6,* 44-49.

Matricciani, L., Olds, T., & Petkov, J. (2012). In search of lost sleep: Secular trends in the sleep time of school-aged children and adolescents. *Sleep Medicine Reviews, 16,* 203-211.

Meijer, A. M., Habekothe, H. T., & Van Den Wittenboer, G. L. H. (2000). Time in bed, quality of sleep and school functioning of children. *Journal of Sleep Research, 9:* 145-153.

Mercer, P. W., Merritt, S. L., & Cowell, J. M. (1998). Differences in reported sleep need among adolescents. *Journal of Adolescent Health, 23,* 259–263.

Mitru, G., Millrood, D. L., & Mateika, J. H. (2002). The impact of sleep on learning and behavior in adolescents. *Teachers College Record*, *104*, 704–726.

Moore, M. (2012). Behavioral sleep problems in children and adolescents. *Journal of Clinical Psychology in Medical Settings, 19,* 77-83. doi: 10.1007/s10880-011-9282-z

Morsy, A. A. K. & Shalaby, N. S. (2012). The use of technology by university adolescent students and its relation to attention, sleep, and achievement. *Journal of American Science, 8,* 264-270.

National Institutes of Health, National Center on Sleep Disorders Research and Office of Prevention, Education, and Control (1997, August). Working group report on problem sleepiness.

National Sleep Foundation (2000). *Adolescent sleep needs and patterns.* Washington DC: Author.

National Sleep Foundation. (2006). Teens and sleep: Summary of findings. Retrieved from http://www.sleepfoundation.org/article/sleep-america-polls/2006-teens-and-sleep

Noland, H., Price, J. H., Dake, J., & Telljohann, S. K. (2009). Adolescents' sleep behaviors and perceptions of sleep. *The Journal of School Health, 79,* 224–230.

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

Pressman, M. R. (1993). Brain Mapping. In *Encyclopedia of Sleep and Dreaming. (*Vol. 1, pp. 84-85). New York, NY: Macmillan Publishing Company.

Randazzo A. C., Muehlbach, M. J., Schweitzer, P. K., &Walsh, J.K. (1998). Cognitive function following acute sleep restriction in children ages 10-14. *Sleep, 21,* 861-868.

Richardson, G. S. (1993). Circadian Rhythms. In *Encyclopedia of Sleep and Dreaming. (*Vol. 1, pp. 120-123). New York, NY: Macmillan Publishing Company.

Roberts, R. E., Roberts, C. R., & Chen, I. G. (2001). Functioning of adolescents with symptoms of disturbed sleep. *Journal of Youth and Adolescence, 30,* 1–18.

Roberts, R., Roberts, C., & Xing, Y. (2011). Restricted sleep among adolescents: Prevalence, incidence, persistence, and associated factors. *Behavioral Sleep Medicine, 9,* 18-30.

Roffwarg, H.P., Muzic, J.N., & Dement, W.C. (1966). Ontogenetic development of the human sleep-dream cycle. *Science, 152,* 604-619.

Rosenburg, R. S. (1993). Aging and Circadian Rhythms. In *Encyclopedia of Sleep and Dreaming. (*Vol. 1, pp. 12-14). New York, NY: Macmillan Publishing Company.

Sadeh, A. (1993). Activity based measures of sleep. In *Encyclopedia of Sleep and Dreaming. (*Vol. 1, pp. 4-6). New York, NY: Macmillan Publishing Company.

Salzarulo, P., & Fagioli, I. (1995). Sleep for development or development for waking? – Some speculations from a human perspective. *Behavioral Brain Research, 69,* 23-27.

Sbanaban, T. L. (1993) Melatonin. In *Encyclopedia of Sleep and Dreaming. (*Vol. 1, pp. 359-360). New York, NY: Macmillan Publishing Company.

Short, M. A., Gradisar, M., Wright, H., Lack, L. C., Dohnt, H., & Carskadon, M. A. (2011). Time for bed: Parent-set bedtimes associated with improved sleep and daytime functioning in adolescents. *Sleep, 34,* 797-800. doi: 10.5665/SLEEP.1052

Smaldone, A., Honig, J., & Byrne, M. (2007). Sleepless in America: Inadequate sleep and relationships to health and well-being of our nation's children. *Pediatrics, 119*, S29-S37. doi: 10:1542/peds.2006-2089F

Strauch, I. & Meier, B. (1998). Sleep need in adolescents: a longitudinal approach. *Sleep, 11,* 378–386.

Talbot, L. S., McGlinchey, E. L., Kaplan, K. A., Dahl, R. E., & Harvey, A. G. (2010). Sleep deprivation in adolescents and adults: changes in affect. *Emotion.* Advance online publication. doi: 10.1037/a0020138

Tarokh, L., Carskadon, M. A., & Achermann, P. (2012). Dissipation of sleep pressure is stable across adolescence. *Neuroscience, 216,* 167-177.

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

Teufel, J. A., Brown, S. L., & Birch, D. A., (2007). Sleep among early adolescent students. *American Journal of Health Studies, 22*, 10-18.

Thorleifsdottir, B., Bjornsson, J. K., Benediktsdottir, B., Gislason, T., & Kristbjarnarson, H. (2002). Sleep and sleep habits from childhood to young adulthood over a 10-year period. *Journal of Psychosomatic Research, 53,* 529-537.

Torrance, E. (1990). *Torrance Tests of Creative Thinking: Manual.* Bensenville, IL: Scholastic Testing Service, Inc.

Van den Bulck, J. (2007). Adolescent use of mobile phones for calling and for sending text messages after lights out: Results from a prospective cohort study with a one-year follow-up. *Sleep, 30,* 1220-1223.

Van den Bulck, J. (2004). Television viewing, computer game playing, and internet use and self-reported time to bed and time out of bed in secondary-school children. *Sleep, 27,* 101-104.

Wahlstrom, K., Wrobel, K., & Kubow, P. (1998, November). *Minneapolis Public Schools Start Time Study, Executive Summary*. Center for Applied Research and Educational Improvement, University of Minnesota.

Wahlstrom, K. (2010). School start time and sleepy teens. *Archives of Pediatrics and Adolescent Medicine, 164,* 676-677.

Wahlstrom, K. (2002). Changing times: Findings from the first longitudinal study of later high school start times. *NASSP Bulletin, 86,* 3-21. doi: 10.1177/019263650208663302

Warner, S., Murray, G., & Meyer, D. (2008). Holiday and school-term sleep patterns of Australian adolescents. *Journal of Adolescence, 31,* 595-608.

Webb, W. B. (1993a). Individual Differences. In *Encyclopedia of Sleep and Dreaming. (*Vol. 1, pp. 299-302). New York, NY: Macmillan Publishing Company.

Webb, W. B. (1993b). Functions of sleep. In *Encyclopedia of Sleep and Dreaming. (*Vol. 1, pp. 257-259). New York, NY: Macmillan Publishing Company.

Webb, W. B. (1974). Sleep as an adaptive response. *Percept Motor Skills, 38,* 1023-1027.

Wilkinson, R. (1959). Sleep deprivation: Performance tests for partial and selective sleep deprivation. In: L. Abt and B. Riess (Eds.), *Progress in Clinical Psychology,* Vol. 8, Grune and Strattion, New York.

Williams, H., Gieseking, C, & Lubin, A. (1966). Some effects of sleep loss on memory. *Perceptual Motor Skills, 23,* 1287-1293.

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

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

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

Wolfson A. R., Carskadon M. A., Acebo C., Seifer, R., Fallone, G., Labyak, S. E., & Martin, J. L. (2003). Evidence for the validity of a Sleep Habits Survey for adolescents. *Sleep, 26,* 213-216.

Wolfson, A. R., Spaulding, N. L., Dandrow, C., & Baroni, E. M. (2007). Middle school start times: The importance of a good night's sleep for young adolescents. *Behavioral Sleep Medicine, 5,* 194-209. doi: 10.1080/15402000701263809

Table 1

School Characteristics

Variable	School 1	School 2	School 3	School 4	School 5
Population Size					
2009-2010	1659	1322	1401	2105	2353
2010-2011	1714	1285	1405	2111	2327
Ethnicity*					
White	62%	36%	76%	87%	83%
Hispanic	30%	48%	16%	5%	7%
Black	4%	8%	3%	2%	2%
Asian	4%	3%	2%	5%	8%
Other	2%	5%	2%	1%	1%
Gender*					
Female	52%	47%	47%	49%	50%
Male	48%	53%	53%	51%	50%

Note. * Asterisk indicates that data was only available from the 2010-2011 school year.

Table 2

Student Characteristics by AIMS Subject

	Reading		Mathematics		Science		Writing	
	N	%	N	%	N	%	N	%
Ethnicity								
White	3192	73.0	3159	73.2	2912	72.4	3186	72.9
Hispanic	755	17.3	739	17.1	726	18.1	756	17.3
Black	144	3.3	138	3.2	144	3.6	144	3.3
Asian	221	5.1	220	5.1	178	4.4	222	5.1
Pacific Islander	61	1.4	62	1.4	61	1.5	61	1.4
School								
1	904	20.7	900	20.8	848	21.1	908	20.8
2	627	14.3	610	14.1	660	16.4	624	14.3
3	692	15.8	671	15.5	635	15.8	689	15.8
4	1033	23.8	1028	23.8	957	23.8	1029	23.6
5	1117	25.5	1109	25.7	921	22.9	1119	25.6
Gender								
Female	2195	50.2	2169	50.3	2000	49.7	2172	49.8
Male	2169	49.6	2140	49.7	2016	50.1	2188	50.2
Missing	9	0.2	9	0.2	5	0.1	9	.2
SPED								
Yes	362	8.3	352	8.2	318	7.9	360	8.2
Total Sample Size	4373	100.00	4318	100.0	4021	100.0	4369	100.0

Table 3

ODR Student Characteristics

Variable	Total		2009-2010		2010-2011	
	N	%	*N*	%	*N*	%
Student with ODRs	4176	100.0	2027	48.5	2149	51.5
Grade						
9th	1066	25.5	395	19.5	671	31.2
10th	1117	26.7	551	27.2	566	26.3
11th	1054	25.2	516	25.5	538	25.9
12th	939	22.5	565	27.9	374	17.4
School						
One	1092	26.1	550	27.1	542	25.2
Two	606	14.5	304	15.0	302	14.1
Three	1096	26.2	499	24.6	597	27.8
Four	206	4.9	99	4.9	107	5.0
Five	1176	28.2	575	28.4	601	28.0

Table 4

Descriptive Statistics of AIMS Scores by Subject

AIMS Subject Scaled Score	Mean	SD	Variance	Skewness
Reading				
Total	733.20	46.29	2141.67	-0.11
2009-2010	732.86	45.17	2040.24	-0.16
2010-2011	733.54	47.416	2248.27	-0.07
Math				
Total	526.43	49.68	2467.73	0.36
2009-2010	527.21	50.64	3564.34	0.37
2010-2011	525.64	48.86	2369.87	0.35
Science				
Total	518.57	55.17	3043.52	0.19
2009-2010	517.22	52.32	2737.29	0.25
2010-2011	519.99	58.01	3364.78	0.13
Writing				
Total	0.00	1.00	1.00	0.11
2009-2010	0.00	1.00	1.00	-0.09
2010-2011	0.00	1.00	1.00	0.32

Note: Writing scores were standardized in order to be put on the same metric.

Table 5

AIMS Reading Analysis of Variance Results

Source	df	F	Sig.	Partial eta squared
District-Wide				
Start Time	1	0.24	0.63	.00
School 1				
Start Time	1	2.57	0.22	.00
School 2				
Start Time	1	0.85	0.36	.00
School 3				
Start Time	1	0.01	0.94	.00
School 4				
Start Time	1	0.54	0.46	.00
School 5				
Start Time	1	0.14	0.71	.00

Note. * significant at $p < .05$; ** significant at $p < .01$.

Table 6

AIMS Math Analysis of Variance Results

Source	df	F	Sig.	Partial eta squared
District-Wide				
Start Time	1	1.07	0.30	.00
School 1				
Start Time	1	1.73	0.19	.00
School 2				
Start Time	1	2.88	0.09	.00
School 3				
Start Time	1	1.30	0.26	.00
School 4				
Start Time	1	0.06	0.81	.00
School 5				
Start Time	1	2.73	0.10	.00

Note. * significant at $p < .05$; ** significant at $p < .01$.

Table 7

AIMS Writing Analysis of Variance Results

Source	df	F	Sig.	Partial eta squared
District-Wide				
Start Time	1	0.00	1.00	.00
School 1				
Start Time	1	0.16	0.69	.00
School 2				
Start Time	1	0.26	0.61	.00
School 3				
Start Time	1	7.282	0.01	.01
School 4				
Start Time	1	0.12	0.73	.00
School 5				
Start Time	1	1.66	0.20	.00

Note. * significant at $p < .05$; ** significant at $p < .01$.

Table 8

AIMS Science Analysis of Variance Results

Source	df	F	Sig.	Partial eta squared
District-Wide				
Start Time	1	2.54	0.11	.00
School 1				
Start Time	1	1.02	0.31	.00
School 2				
Start Time	1	2.77	0.10	.00
School 3				
Start Time	1	2.20	0.14	.00
School 4				
Start Time	1	0.16	0.69	.00
School 5				
Start Time	1	0.80	0.37	.00

Note. * significant at $p < .05$; ** significant at $p < .01$.

Table 9

Mann-Whitney Analysis of AIMS Performance Scores

AIMS Subject	*Z*	Asymp. Sig. (2-tailed)
Reading	-1.65	0.10
Math	-2.22	0.03*
Writing	-10.22	0.00**
Science	-2.04	0.04*

Note. * significance at $p < .05$; ** significance at $p < .01$

Table 10

Office Discipline Referral (ODR) Descriptive Statistics

Start Time	Mean	Median	SD	Variance	Skewness
2009-2010					
Total ODR	2.38	1.00	2.26	5.11	2.75
First period	0.37	0.00	0.77	0.59	2.83
Attendance	0.82	0.00	1.22	1.49	2.35
Def./Dis./Disr.	0.42	0.00	0.97	0.94	4.30
2010-2011					
Total ODR	2.58	2.00	2.62	6.87	3.33
First period	0.53	0.00	0.97	0.04	2.72
Attendance	1.09	1.00	1.46	2.14	2.35
Def./Dis./Disr.	0.59	0.00	1.29	1.65	4.14

Note. Def./Dis./Disr. represents Defiance, Disrespect, and Disruption.

Table 11

ANOVA for School Start Time and Office Discipline Referrals (ODRS)

Welch Statistic	F	Sig.	Partial eta squared
Total ODR	6.719	0.01**	.002
Def./Dis./Disr.	25.24	0.00**	.006
Attendance	42.89	0.00**	.010
First Period	33.61	0.00**	.008

Note. * significance at p < .05; ** significance at p < .01.
Def./Dis./Disr. represents Defiance, Disrespect, and Disruption.

Table 12

Office Discipline Referral (ODRS) across High School Population

	2009-2010		2010-2011	
High School Students	*N*	%	*N*	%
Total Population	8840	100	8842	100
With ODRs	2027	23	2149	24
No ODRs	6823	77	6693	76
School Level				
One				
With ODRs	550	33.0	542	31.6
No ODRs	1109	67.0	1172	68.4
Two				
With ODRs	304	23.0	302	23.5
No ODRs	1018	77.0	983	76.5
Three				
With ODRs	499	35.6	597	42.5
No ODRs	902	64.4	808	57.5
Four				
With ODRs	99	4.7	107	5.1
No ODRs	2006	95.3	2004	94.9
Five				
With ODRs	575	24.4	601	25.8
No ODRs	1778	75.6	1726	74.2