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Comparing Before-and After-School Neurocognitive Performance in High School Athletes: Implications for Concussion Management

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Implications for Concussion Management

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Abstract

Background: Sport-related concussion (SRC) continues be a hot topic in sports medicine. Computerized Neurocognitive Testing (CNT) provides researchers and sports medicine professionals an objective way to manage SRC. Administering CNT comes at the convenience of the student athlete and the sports medicine professional working at the school, which usually results in CNT being administered in the afternoon, or after school. However, little is known how the cognitive fatigue of attending a full day of school influences CNT performance.

Purpose: The purpose of this study was to compare before school CNT performance to after school CNT performance in a sample of non-concussed high school student athletes. An exploratory question was posed to evaluate the frequency of chronotypes in a sample of non-concussed high school athletes.

Study Design: A posttest only, non-equivalent groups design was used for the study.

Methods: There were 31 high school athletes who completed the computerized baseline neurocognitive test. Thirteen athletes completed the test in the morning (before school) and 18 athletes completed the test in the afternoon (after school). Means comparisons for neurocognitive performance were evaluated between the two groups. An independent samples t-test was used to compare the mean ImPACT scores of the two groups and a statistical significance was set at a Bonferroni-corrected $p \leq .05$. The Morningness/Eveningness Questionnaire (MEQ-SA) was administered to thirteen athletes in the morning (before school) testing session. A frequency table was constructed to compare athletes' specific chronotypes in the morning testing session.

Results: Results from an independent-samples t-test revealed similar performance on verbal memory ($t(29) = -1.02$, $p = .31$), visual memory ($t(29) = 1.01$, $p = .32$), motor processing speed ($t(29) = 0.007$, $p = .994$), reaction time ($t(29) = -0.58$, $p = .57$), or total symptom scores ($t(29) = -$

1.53, $p = .14$) between the two groups. A frequency table was constructed to compare chronotypes in sample of non-concussed high school student athletes.

Discussion: The results of this study suggest that completing a computerized neurocognitive test in the morning (before school) or in the afternoon (after school) does not influence performance.

Introduction

Imagine a clinical scenario in which the starting middle linebacker at a prestigious high school football program sustains a concussion. The injury is appropriately diagnosed on the sideline and the athlete is appropriately managed during the following week. During this time the athlete's neurocognitive status is assessed via a computerized neurocognitive test battery several times and the athlete shows gradual improvement. The athlete is attending classes and plans to play the school's cross-town rival on the upcoming Friday night. However, the athlete needs to "pass" his "concussion test" on Wednesday to be cleared to play that Friday night. The athlete attends a full day of school on Wednesday and is administered the neurocognitive battery later in the afternoon (e.g., 3:00 p.m.). The athlete scores below his baseline, but reports his poor performance is due to cognitive fatigue from the academic demands of school, not his concussion. The sports medicine professional is unsure of what to make of these data, given that the athlete is highly motivated to play on Friday and may be using school as an excuse to account for this performance. This story is a common clinical dilemma for the sports medicine professional that can be addressed by research that investigates factors that influence performance on neurocognitive tests used for concussion management.

Sport-related concussion (SRC) continues to be a hot topic in sports medicine. Recent incidence rates estimate that 1.6 to 3.8 million sport-related concussions occur annually in the United States (Langlois, Rutland-Brown, & Wald, 2006). Recently, the assessment and management approach for SRC has shifted from relying on athlete's subjective, self-reported symptoms (i.e., "Tell me how you are feeling?") to more objective neurocognitive assessment that provides objective quantifiable data on the current cognitive status of the injured athlete.

Although post-concussion symptom assessment remains the centerpiece for concussion management, more objective measures, such as computerized neurocognitive testing (CNT), provide additional value and objectivity to the management of concussion (McCrory et al., 2013;Van Kampen, Lovell, Pardini, Collins, & Fu, 2006). Neurocognitive batteries used for assessing the effects of concussion are comprised of measures of memory, concentration, processing speed, and reaction time, which are commonly impaired following a SRC (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009; Makdissi et al., 2001; Schatz, Pardini, Lovell, Collins, & Podell, 2006). It is recommended best practice to administer these batteries in a prospective manner that involves a pre-season or baseline assessment to allow for comparison to post-concussion performance. The accuracy of both pre and post injury assessments is critical for making appropriate clinical decisions, with respect to return to play.

Researchers have identified several factors that negatively influence CNT performance in healthy individuals. History of previous concussion (Collie, McCrory, & Makdissi, 2006), sex (Covassin, Elbin, Harris, Parker, & Kontos, 2012), attention deficit hyperactivity disorder (ADHD) and learning disability (LD) (Elbin, Kontos Kegel, Johnson, Burkhart, & Schatz, 2013), motivation (Bailey & Arnett, 2006), sleep quality/quantity (Mihalik et al., 2013) and physical fatigue (Covassin, Weiss, Powell, & Womack, 2007) have all been shown to negatively influence performance on neurocognitive assessments. With regard to the age of the concussed athlete, a recent study found that high school athletes and collegiate athletes exhibited different outcomes after concussion (Covassin, Elbin, Harris, Parker, & Kontos, 2012). The results suggested that high school concussed athletes performed worse than college-concussed athletes on verbal and visual memory (Covassin, Elbin, Harris, Parker, & Kontos, 2012). While these factors are all important for the sports medicine professional to consider, the potential deleterious effects from the cognitive demands of the academic setting (i.e., testing before or after school) combined with the time of CNT administration (i.e., before or after school) have not been examined.

High school athletes that have sustained a concussion may still be required to attend class and complete an academic school day. The sports medicine professional is required to work around the academic schedule when completing concussion management protocol. Administering CNT after a completed academic school day may not be the optimal time to evaluate neurocognitive function due to the potential confounding effects of decreased motivation and increased cognitive fatigue after school and fluctuations in circadian rhythm that occurs during the late afternoon hours (Barnard & Nolan, 2008; Czeisler & Gooley, 2007).

According to circadian arousal pattern, in chronopsychology and chronobiology, individuals can be described considering their circadian typology or chronotype (Fabbri, Mencarelli, Adan, & Natale, 2013; Jovanovski & Bassili, 2007; Randler & Frech, 2006; Roenneberg, Wirz-Justice, & Merrow, 2003). The two chronotypes, morning-types and evening-types, differ in cognitive efficiency during the day (Fabbri, Mencarelli, Adan, & Natale, 2013; Horne et al., 1980; Natale, Alzani, & Cicogna, 2003). Previous research suggests that the individual differences in circadian arousal levels at particular times of day influence the type of information processing strategies that individuals adopt (Bodenhausen, 1990; Fabbri, Mecnarelli, Adan, & Natale, 2013).

The primary purpose of the current study is to compare before-school CNT performance to after-school CNT performance in a sample of non-concussed high school athletes.

Hypothesis

H1: After-school neurocognitive performance will be lower than before-school neurocognitive performance in high school student athletes.

Exploratory Question

E1: To explore differences in frequency of chronotypes in a sample of non-concussed high school athletes.

Review of Literature

Sport-related concussion (SRC) continues to be a hot topic in sports medicine. Concussion, also known as mild traumatic brain injury (mTBI), is defined as a "complex pathophysiological process affecting the brain, induced by biomechanical forces" (McCrory et al., 2013, p. 555). Concussion presents with a wide variety of signs, symptoms, and impairments that are unique to each concussed athlete. Recent incidence rates estimate that 1.6 to 3.8 million sport-related concussions occur annually in the United States (Langlois, Rutland-Brown & Wald, 2006). This estimate is considered low because many concussions go unrecognized and unreported (Langlois, Rutland-Brown & Wald, 2006).

Prevalence of Sport-Related Concussion

In a previous study, researchers investigated the prevalence rate of concussions in a large sample of high school and collegiate athletes to compare incidence rates between the two groups. Two databases were used to collect data for the study. In the 2005-2006 High School Sports-Related Injury Surveillance Study, Reporting Information Online, was used to examine the exposure rates of concussion in nine popular high school sports, boys' football, soccer, basketball, wrestling, baseball and girls' soccer, volleyball, basketball, and softball (Gessel, Fields, Collins, Dick, & Comstock, 2007). Also used was the National Collegiate Athletic Association Injury Surveillance System (NCAA ISS) (Gessel, Fields, Collins, Dick, & Comstock, 2007).

Of the nine high school sports studied over the course of 2005-2006, 4,431 injuries were reported, and 396 (8.9%) were concussions (Gessel, Fields, Collins, Dick, & Comstock, 2007). The weighted national estimate for the number of concussions sustained in all sports was 135,901(Gessel, Fields, Collins, Dick, & Comstock, 2007). Based on the national estimate, the majority of concussions occurred in football (40.5%) followed by girls' soccer (21.5%), boys' soccer (15.4%) and girls' basketball (9.5%) (Gessel, Fields, Collins, Dick, & Comstock, 2007). Similar results were found for the 9 sports examined from the NCAA ISS. A total of 8,293 injuries were reported and of those 482 were concussions (5.8%) (Gessel, Fields, Collins, Dick, & Comstock, 2007). As the number of high school athletes and collegiate athletes continues to increase, so will the number of concussions.

Biomechanics of Sport-Related Concussion

A sport-related concussion can occur from the result of a linear impact or rotational movement (Bailes & Cantu, 2001). A linear impact occurs when the athlete's body and head a traveling at a certain speed and come in contact with a solid object (Bailes & Cantu, 2001). Another scenario would be that an athlete's head is stationary and is struck by a moving object (Bailes & Canu, 2001). Rotational movement occurs when the head is hit at some angle and responds by rotating (Stemper & Pintar, 2014). In recent years technology has been used as a tool to predict the likelihood of a concussion through a monitoring system. The Head Impact Telemetry System (HITS) is a wireless monitoring system that provides real time, post-impact data to a clinician on the sideline (Broglio et al., 2009; Crisco, Chu, & Greenwald, 2004). Several studies have used HITS to compare the force at which the athlete is hit to the sport the athlete plays. An early study found that linear acceleration is mostly responsible for concussion with a mean threshold for injury to be 98g and an impact generating a minimum 70-75g necessary to cause injury in elite athletes (Pellman et al., 2003). However, data collected from the high school level indicated that high school football athletes' 271 impacts exceeded the 70g threshold and 78 impacts exceeded the 98g magnitude with only five reported concussive injuries (Broglio et al., 2009). One of the most important studies found that there was no relationship between the magnitude of the impact and the injury severity measured by decrease in postural control, neurocognitive functioning, and increased symptoms reports (Guskiewicz et al., 2007). Even though high school concussion incidence rates are nearly identical to those of collegiate athletes and professional athletes, researchers have concluded that a high school athlete's immature musculoskeletal system and diminished ability to control and slow down their head after impact is to blame for similar incidence rates even though high school football games are slower and less physical, resulting in lower impact forces (Broglio et al., 2009; Broglio et al., 2010). Injuries develop within the tissues of the brain as the strains are transferred from the outer to the inner regions by way of neurometabolic cascade (Stemper, 2014).

Pathophysiology of Sport-Related Concussion

The series of cellular events that take place as a result from traumatic direct and/or indirect impact to the head is called neurometabolic cascade. Neurometabolic cascade is used to describe a complex series of functional injury and microstructural injury changes (Giza, 2014). Specifically, the neurometabolic cascade of events involves bioenergetic challenges, cytoskeletal and axonal alterations, impairments in neurotransmission, vulnerability to delayed cell death and chronic dysfunction (Barkhoudaria, Hovda, & Giza, 2011; Giza & Hovda, 2001). Immediately after a concussion there is an influx of calcium ions and an efflux of potassium ions (Giza & Hovda, 2001). In order to restore the neuronal membrane potential the sodium-potassium pump, which requires adenosine triphosphate (ATP), must go into over drive requiring increasing amounts of ATP (Giza & Hovda, 2001). As the sodium-potassium pump works in overdrive there is a significant increase in glucose metabolism, "hypermetabolism", that decreases cerebral blood flow and creates a huge difference in glucose supply (Giza & Hovda, 2001). The result is a mismatch between energy supply and energy demand, also called an energy crisis (Giza &

Hovda, 2014). Post-concussion physiological changes have been shown to increase the brain's vulnerability to further injury making it imperative that the athlete is properly managed to avoided catastrophic injury. (Shrey, Griesback, & Giza, 2011). The microscopic events that take place in the brain during neurometabolic cascade may present as a myriad of symptoms and impairments.

Signs, Symptoms, and Impairments of Sport-Related Concussion

Sport-related concussion is characterized by an inconsistent symptom presentation, meaning that the symptoms vary from athlete to athlete. Not all athletes present with the same symptoms and impairments, which makes the assessment and management of sport-related concussion difficult. It is important for clinicians to recognize the on field signs and symptoms in order for them to make appropriate management decisions to determine whether the athlete should return to play. Symptoms that present on-field include: confusion, headache, loss of consciousness, posttraumatic amnesia, retrograde amnesia, imbalance, dizziness, visual problems, personality changes, fatigue, sensitivity to light and noise, numbness, and vomiting (Lau, Kontos, Collins, Mucha, & Lovell, 2011). Specifically, symptoms can be categorized into four clusters: cognitive-fatigue-migraine (e.g, headache, difficulty concentrating, fatigue, dizziness), affective (e.g, sadness, nervousness), somatic (e.g, nausea, numbness), and sleep (e.g, trouble sleeping, sleeping less than usual) (Kontos et al., 2012).

Recently, the assessment and management approach for SRC has shifted from relying on athlete's subjective, self-reported symptoms (i.e., "Tell me how you are feeling?") to more objective neurocognitive assessment that provides objective quantifiable data on the current cognitive status of the injured athlete.

The post-concussion symptom assessment remains an important part of the clinical interview for SRC and remains a centerpiece for concussion management. However, numerous studies have reported that athletes commonly withhold and/or minimize their concussion symptoms in hopes to avoid being removed from play or even expedite their return to play (RTP) (Van Kampen, Lovell, Pardidni, Collins, & Fu, 2006). As a result, recent consensus statements have advocated for the use of more objective measures when assessing the cognitive status of a concussed athlete that will help corroborate subjective symptom reports (McCrory et al., 2013). Computerized neurocognitive testing (CNT) is one tool that has been widely implemented for concussion management and provides a valuable, yet objective complement to athlete symptom reports (Van Kampen, Lovell, Pardini, Collins, & Fu, 2006).

Computerized Neurocognitive Assessment

Computerized neurocognitive testing (CNT) includes a battery of cognitive tasks, based on traditional paper-and-pencil neuropsychological tests that measure verbal memory, visual design memory, concentration, visual processing speed, and reaction time that are commonly affected following SRC (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009; Makdissi et al., 2001; Schatz, Pardini, Lovell, Collins, & Podell, 2006). CNT is best administered in a prospective manner that involves a pre-season or baseline assessment to allow for comparison to post-concussion performance. In the absence of a baseline, normative data for age and gender are available for post-concussion comparison of scores. Computerized neurocognitive testing has many advantages that include: the ability to baseline test groups of athletes concurrently (i.e., 10-15 every 20 minutes), ease of administration and scoring, alternate test forms to reduce practice effects, and creation of centralized data repositories for ready access by users (Guskiewiez et al., 2004; Woodard & Rahman, 2012). Another important advantage of CNT is that it does not require direct involvement of a licensed neuropsychologist for test administration, scoring, and interpretation (Resch, McCrea, & Cullum, 2013). While CNT is a valuable tool for assessing and managing concussion, the sports medicine professional must be aware of confounding factors that may influence performance on these assessments.

Factors that Influence Computerized Neurocognitive Testing

Researchers have identified several factors that negatively influence CNT performance. A history of previous concussion (Collie, McCrory, & Makdissi, 2006) is one factor that can negatively influence CNT performance. A previous study followed 598 high school and college athletes over a six-year period. Evidence showed that athletes with a history of three or more concussions took longer than eight days to recover, significantly longer than those with one or no previous concussions (Covassin, Moran & Wilhelm, 2013). Specially, the athletes with a previous history of concussion took longer to recover on verbal memory, had slower reaction times, and had a greater number of cognitive-fatigue-migraine symptoms (Covassin, Moran, & Wilhelm, 2013). Differences in sex (Covassin, Elbin, Harris, Parker, & Kontos, 2012) also negatively influences CNT performance. A previous study examined female and male neurocognitive performance scores to compare the differences between the two sexes in verbal memory, visual memory, visual processing speed, and reaction time. The evidence showed the female athletes preformed worse on visual memory than the male athletes (Covassin, Elbin, Harris, Parker, & Kontos, 2012). Recent studies indicated that together, attention deficit hyperactivity disorder (ADHD) and learning disability (LD) (Elbin et al., 2013) decrease cognitive performance on measures of reading, working memory, processing speed, response inhibition, phonological awareness, and set shifting (Purvis & Tannock, 1997; Willcutt et al., 2001). Motivation (Bailey & Arnett, 2006), sleep quality/quantity (Mihalik et al., 2013) and physical fatigue (Covassin, Weiss, Powell, & Womack, 2007) have also been linked with lower performance on neurocognitive assessments.

While these factors are all important for the sports medicine professional to consider, the potential deleterious effects that cognitive fatigue from the academic setting (i.e., testing before or after school) has on CNT performance has not been examined.

Cognitive Demand and Neurocognitive Performance

High school athletes that sustain a concussion may still be required to attend classes and complete an academic school day. Therefore, the sports medicine professional is required to work around the academic schedule, which influences when CNT can be administered. Oftentimes the earliest opportunity for CNT administration is at the conclusion of the high school academic day (i.e., approximately 2-3pm in the afternoon), which may not be an optimal time to evaluate neurocognitive function due to the potential confounding effects of decreased motivation and increased fatigue after school and fluctuations in circadian rhythm that occurs during the late afternoon hours (Barnard & Nolan, 2008; Czeisler & Gooley, 2007).

Cognitive fatigue and CNT performance

Previous research has demonstrated that cognitive performance is adversely affected by increased cognitive fatigue (Benca, Duncan, Frank, McClung, Nelson, & Vicentic, 2009). Mental or cognitive fatigue describes the effects that people may experience after long periods of cognitive activity, like school (Boksem, Meijman, & Lorist, 2005). Cognitive fatigue can influence mood, motivation, and attention, which are all imperative when taking CNT to determine RTP (Van der Linden, 2010). An early study was conducted on pilots who were required to fly a simulator for long periods of time, the pilots reported the periods of decreased attention increased the longer they were flying and with that the operators became more distracted (Bartlett, 1943). In a more recent study seventeen healthy college students were used to see the effects of mental fatigue on attention (Boksem, Meijman, & Lorist, 2005). The subjects were told to preform a task continuously for three hours without rest (Boksem, Meijman, & Lorist, 2005). The subjects reported an increase in difficulty staying alert and sustaining attention as the three hours went on (Boksem, Meijman, & Lorist, 2005). In addition, cognitive performance is affected by natural fluctuations in circadian rhythm (Benca et al., 2009).

Cognition and Circadian Rhythm

Circadian rhythms "are endogenously driven biological variations that fluctuate with a periodicity of approximately 24 hours" (Benca, Duncan, Frank, McClung, Nelson, & Vicentic, 2009, p. 2). The circadian pacemaker is located in the hypothalamic surpachiasmatic nucleus (SCN) and controls many physiological and behavioral variables via clock controlled genes that regulate the output rhythms throughout the central nervous system and periphery (Benca et al., 2009). The circadian timing system regulates sleep-wake cycles as well as rhythms in cognitive processes including: subjective alertness, mathematical ability, arousal, learning and memory (Benca et al., 2009). As well as circadian rhythm, cognition varies throughout a 24-hour period. Cognition patterns are driven by three neurobiological processes: sleep inertia, the phenomenon of decreased performance and/or disorientation occurring immediately after awakening from sleep relative to pre-sleep status, homeostatic sleep drive, and circadian rhythm (Tassi & Muzet, 2000; Wright, Lowry, & LeBourgeois, 2012). Several studies have been conducted to examine the cognitive effects of misalignment in circadian rhythm in adolescents. The findings suggest that circadian rhythm misalignments in adolescents could have a negative effect in cognitive functioning (Wright, Lowry, & LeBourgeois, 2012). First, early school start times require adolescents to perform at a certain cognitive level before the waking-promoting effects of the circadian system are fully in mode (Carskadon et al., 1998). Second, executive cognitive function varies throughout the day, and studies suggest that adolescents perform better in the afternoon rather than the morning (van der Heijden, de Sonneville, & Althaus, 2010). This finding is supported by the fact that circadian rhythm varies throughout a lifetime. Children are more morning oriented, when it comes to cognitive functioning (Randler, Fontius, & Vollmer, 2012). During adolescence, circadian rhythm transitions towards evening orientation (Andrade et al., 1993; Diaz-Morale & Gutierrez 2008; Gianotti et al., 2002).

Sleep and Circadian Rhythm

The sleep-wake cycle is “regulated by two mechanisms acting either in synchrony or in opposition to each other along the 24-hr cycle: the homeostatic process, which strives to balance the time spent awake and asleep, and the circadian timing process”, or biological clock (Schmidt, Collette, Cajochen, & Peigneux, 2007, p. 756). The intention of the circadian process is for wakefulness to take place during the day and sleep to take place at night (Schmidt, Collette, Cajochen, & Peigneux, 2007). Multiple studies show that effects of shortened sleep on daytime functioning are sleepiness, tiredness, difficulty getting up, moodiness as well as diminished attention and concentration difficulties in school (Carskadon, Vieira, & Acebo, 1993; Epstein, Chillag, & Lavie, 1998; Gau & Soong, 1995). An early study followed 24 healthy men to find the interaction between the sleep-wake cycle and circadian fluctuations on alertness and performance (Dijk, Duffy, & Czeisler, 1992). The study found that when the men’s environment was controlled, alertness and cognitive performance remained fairly stable throughout the waking hours of a day (Dijk, Duffy, & Czeisler, 1992). However, when wakefulness was extended alertness, performance decreased significantly (Dijk, Duffy, & Czeisler, 1992). These findings are particularly interesting when looking at the sleeping habits of adolescents. Although lack of sleep can negatively affect cognitive performance, studies show that fluctuations in circadian rhythm is linked to decreased cognitive performance later in the day (Barnard & Nolan, 2008; Czeisler & Gooley, 2007).

Morningness versus Eveningness Chronotypes

According to circadian arousal pattern, in chronopsychology and chronobiology, individuals can be described considering their circadian typology or chronotype (Jovanovski & Bassili 2007; Randler & Frech, 2006; Roenneberg, Wirz-Justice, & Merrow, 2003). Max arousal can be reached "either in the morning or in the evening, according to circadian typology" (Fabbri, Mencarelli, Adan, & Natale, 2013, p. 126). The individual's preference for the timing of daily activities is associated with markers of circadian physiology such as the peak, amplitude or period of core body temperature, melatonin and cortisol (Baehr, Revelle, & Eastman, 2000; Deffy et al., 1999; Horne & Ostberg 1976).

The two chronotypes, morning-types and evening-types, differ in cognitive efficiency during the day (Horne et al., 1980; Natale, Alzani, & Cicogna, 2003). Previous research suggests that the individual differences in circadian arousal levels at particular times of day influence the type of information processing strategies that individuals adopt (Bodenhausen, 1990). Specifically, strong evidence suggests that superior cognitive functioning occurs when testing times are synchronized with individuals' peak circadian arousal periods, referred to as the synchrony effect (Anderson, Petros, Beckwith, Mitchell, & Fritz, 1991; Petros, Beckwith, & Anderson, 1990). The synchrony effect echoes the idea that morning-types perform better in the morning than in the afternoon and evening-types show the reverse pattern on a range of cognitive tasks, including negative priming, false memory, recognition and recall of prose and span materials, categorization, impression formation, judgment and control over distraction and working memory (Bodenhausen, 1990; Hasher, Chung, May, & Foong, 2002; Hasher, Goldstein, & May, 2005; Intons-Peterson, Rocchi, West, McLellan & Hackney, 1998; Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1999; May, Hasher, & Stoltzfus, 1993; May, Hasher, & Foong, 2005; May & Hasher, 1998; May, 1999; Rowe, Hasher, & Turecotte, 2009; Yang, Hasher, & Wilson, 2007). Therefore, these data suggest that the timing of administration and normal fluctuations in circadian rhythm could negatively influence CNT performance.

Methods

Research Design: A posttest only, non-equivalent groups design was used to compare differences in CNT performance between morning and afternoon testing occasions.

Participants: Sixty-three non-concussed high school athletes currently participating in the UofA Sport Concussion Surveillance Program were qualified to participate in this study. Athletes that reported previous diagnosed learning disability (LD), attention deficit hyperactivity disorder (ADHD), or endorsed English as a second language were excluded from participation.

Measures/Instrumentation:

Demographics: Demographic data includes age, sex, grade level, history of migraine/headache, ADHD, LD, previous concussion, and previous night's sleep, were assessed via Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery.

Neurocognitive Performance: CNT performance was measured with the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery. The ImPACT battery takes approximately twenty-five minutes to complete, has five different test versions to minimize practice effects, and produces composite scores for the cognitive domains of verbal memory, visual memory, motor processing speed, and reaction time. The ImPACT battery has demonstrated acceptable validity and reliability over eight days across four administrations, yielding correlation coefficients ranging from $r = .62$ to $r = .88$ for outcome scores (Iverson, Lovell, & Collins, 2005). ImPACT also assesses current symptom reports via the Post-Concussion Symptoms Scale (PCSS), which is a twenty-two-item seven-point Likert symptom inventory and total reported symptoms will be used as an outcome variable. The reliability and validity of the PCSS have been well documented in previous studies (Lovell et al., 2006)

Morningness/ Eveningness Questionnaire (MEQ-SA):

The Morningness/Eveningness Questionnaire uses sleep-related questions to determine and evaluate circadian rhythm patterns in the athletes. The questionnaire contains nineteen questions that examine sleep habits and fatigue. After completion of the questionnaire, the score is calculated by adding up the number of points of each question. The points can range from sixteen to eighty-six. Scores forty-one and below indicate “evening-types”, while scores fifty and above indicate “morning types”. Scores between forty-two and fifty-eight indicate “intermediate types”. The reliability and validity of the MEQ-SA have been well documented in previous studies (Horne & Ostberg, 1976).

Procedures:

Upon obtaining University IRB approval, researchers initially recruited sixty-three high school student-athletes participating in the UofA Sport Concussion Surveillance Program. However, because of inclement weather and unavailable testing centers at the local high school, thirty-one athletes completed the study. After receiving parental consent and child assent, participants were randomly assigned into either a morning (before school, n =13) testing session or afternoon (after school, n = 18) testing session in the middle of the academic week (Wednesday). Athletes were instructed to get approximately eight hours of sleep, eat breakfast/lunch, and refrain from ingesting caffeine 3 hours prior to testing. Athletes completed the ImPACT battery in the high school’s designated computer lab at their assigned morning (before school) or afternoon (after school) time. Athletes completed the ImPACT battery in supervised groups. During the morning testing sessions the athletes completed the Morningness/Eveningness Questionnaire (MEQ-SA). In an effort to mitigate poor effort when completing the neurocognitive battery, the current study used an instructional script and deception. Specifically, the athletes were told that compensation for the study depended on their effort and performance (i.e., higher effort and scores will equate to maximum cash prize). The athletes that completed the morning (before school) and afternoon (after school) testing sessions received the forty dollars cash prize, regardless of their effort.

Data Analysis:

A statistical analysis was conducted with SPSS. Descriptive statistics along with means comparisons on confounding variables (e.g., age, sex, height, weight, previous number of concussions, and hours of sleep prior to testing) were conducted to determine equality between the two time points (morning/afternoon).

H1: After-school neurocognitive performance will be lower than before-school neurocognitive performance in high school student athletes.

Hypothesis 1 was examined with a series of independent-samples t-tests. The independent variable was time (morning/afternoon) and dependent variables were the ImPACT composite scores of verbal memory, visual memory, motor processing speed, and reaction time. In addition, total symptom score on the PCSS was a dependent variable. Statistical level of significance was set at a Bonferroni-corrected $p \leq .05$.

E1: To explore differences in frequency of chronotype in a sample of non-concussed high school athletes.

The exploratory question was addressed with a frequency table. There was not sufficient evidence to conduct a series of independent-samples t-tests.

Results

Demographic Information

There were a total of 31 high school athletes who participated in this study (n = 13 in morning (before school), n = 18 in afternoon (after school)). The total sample consisted of 14 females and 17 males. The average age of the participants was 16.12 years (*SD*= 1.13). The average height and weight of the participants was 167.97 cm (*SD*= 7.27) and 67.80 kg (*SD*= 15.21). Out of the total sample of participants, the average number of concussions was .03 (*SD*= .18). There were no significant differences between the two groups on age (t (29) = -0.377, p = .71), height (t(29) = 1.90, p = .07), weight (t(29) = 0.32, p = .75), previous number of concussions (t(29) = -0.85, p = .41), or hours of sleep prior to testing (t(26) = 0.37, p = .71). In addition there were no significant differences of sex between the before and after school groups (X^2 (1, n=31) = 0.07, p = .79). Means and standard deviation for these variables are displayed in Table 1.

Table 1

Means, standard deviations, and range for demographic characteristics of the morning (n = 13) and afternoon (n = 18) groups.

	Morning			Afternoon			TOTAL		
	M	*SD*	*RANGE*	*M*	*SD*	*RANGE*	*M*	*SD*	*RANGE*
Age (yrs.)	16.03	0.81	14.76-17.43	16.19	1.33	14.52-18.14	16.12	1.13	14.52-18.14
Height	170.77	8.43	154.94-185.42	165.95	5.71	152.40-175.26	167.97	0.51	152.40-185.42
Weight	68.84	17.80	45.36-108.86	67.06	5.71	47.17-92.99	67.80	15.21	45.36-108.86
Concussion History	0.00	0.00	0.0-0.0	0.06	0.24	.00-1.00	0.03	0.18	.00-1.00
Hours of Sleep	7.58	1.20	5.50-10.00	7.43	0.82	6.00-8.50	7.50	1.00	5.50-10.00

	n	%	*n*	%	*n*	%
% Female	5	38.5%	9	50.0%	14	45.2%

*$p \leq .05$

Evaluation of Hypothesis and Exploratory Question

H1: After-school neurocognitive performance will be lower than before-school neurocognitive performance in high school student athletes. An independent-samples t-test was conducted to compare ImPACT composite scores for morning (before school) CNT testing and afternoon (after school) CNT testing. There were no significant differences in verbal memory ($t(29) = -1.02$, $p = .31$), visual memory ($t(29) = 1.01$, $p = .32$), motor processing speed ($t(29) = 0.007$, $p = .994$), reaction time ($t(29) = -0.58$, $p = .57$), or total symptom scores ($t(29) = -1.53$, $p = .14$) between the two groups. Means and standard deviations for these variables are displayed in Table 2.

Table 2

Means and standard deviations for morning (n = 13) and afternoon (n = 18) neurocognitive and symptom scores

Variable	Morning		Afternoon	
	M	*SD*	*M*	*SD*
Verbal Memory (% correct)	87.54	7.48	90.89	9.92
Visual Memory (% correct)	84.62	10.70	80.39	11.97
Motor Processing Speed	37.62	3.81	37.60	6.38
Reaction Time (sec.)	0.56	0.04	0.58	0.07
Total Symptoms	6.62	7.60	14.67	17.82

*$p \leq .05$

E1: To explore differences in frequency of chronotype in a sample of non-concussed high school athletes.

There were a total of thirteen high school athletes who completed the Morningness/Eveningess Questionnarie (MEQ-SA) in the morning (before school) testing session. The sample consisted of five females and eight males. There were two athletes who qualified as “morning types”, two athletes who qualified as “evening types”, and nine athletes who qualified as intermediate types. The frequencies of chronotypes from the morning (before school) testing group are described in Table 3.

Table 3

Frequency table of chronotypes from morning (before school) testing group (n =13)

Chronotype	*n*	%
Morning Type	2	15.4%
Evening Type	2	15.4%
Intermediate Type	9	69.2%

Discussion

The purpose of this project was to compare before school CNT performance to after school CNT performance in a sample of non-concussed high school athletes. There were no significant differences in the two groups regarding mean demographic information. The results of this study found no significant differences between mean ImPACT composite scores (e.g., verbal memory, visual memory, motor processing speed, reaction time, or total symptoms). Further testing is needed to corroborate these findings.

Originally, the design of this study was to be a randomized crossover design. The participants would attend the first testing session either in the morning (before school) or afternoon (after school). After completing the first testing session the participants would switch and attend the opposite testing time a week later. However, due to inclement weather that canceled two of the three testing days, participants were only able to complete the first testing session. This altered the design of this study. This study compared ImPACT composite scores of the morning (before school) testing group to the afternoon (after school) testing group.

The original purpose of this study was to determine if cognitive fatigue from an academic school day influenced CNT performance. The results of this study do not give an appropriate answer to the original question. We cannot say that cognitive fatigue from a school day influenced CNT performance, because the measure that was used to quantify cognitive fatigue from a day of school was not administered to the entire sample. The Cognitive Demand of School Intake Form was only administered to the athletes during the afternoon (after school) testing session, and because of inclement weather, the athletes from the morning (before school) testing session were unable to complete the afternoon (after school) session.

Without the influence of weather, the athletes would have been able to complete the study. The athletes would have attended both testing sessions within a week of each other and would have completed all of the measures listed above. This would have allowed researchers to determine if cognitive fatigue from a school day influenced CNT performance.

In conclusion, more testing is needed to determine if ImPACT composite scores differ when CNT testing is administered in the morning (before school) or afternoon (after school) in non-concussed high school athletes.

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