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

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

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Abstract

There are several factors that influence computerized neurocognitive testing performance however, one factor that has not been examined is the potential deleterious effects of cognitive fatigue from an academic school day combined with time of computerized neurocognitive testing (CNT) administration. The primary purpose of this study was to compare before-and after-school CNT performance and total symptoms in non-concussed high school student athletes. The secondary purpose of this study was to compare before-school and after-school CNT performance and total symptoms and chronotypes in non-concussed student athletes. A crossover design was used to compare before-and after-school CNT performance and total symptoms of 39 non-concussed high school student athletes with an average age of 15.74 (SD = 1.04). Based on previous literature a hypothesis was made that high school student athletes would report higher self-reported fatigue after-school than before-school. Differences in CNT performance and total symptoms were measured by comparing composite scores of verbal memory, visual memory, processing speed, reaction time and total symptoms. In addition, to main outcome measures, several measures were used to control for potential confounding factors that could influence CNT performance. Before-school self-reported fatigue (M = 3.83, SD = 1.64) was significantly higher than after-school (M = 3.06, SD = 1.91) self-reported fatigue. There were no significant differences in verbal memory $t(38) = 0.80$, $p = .43$, visual memory $t(38) = -0.78$, $p = .44$, processing speed $t(38) = .07$, $p = .94$, reaction time $t(38) = 1.45$, $p = .16$, or total symptoms $t(38) = -0.64$, $p = .52$, between before-school and after-school. Lastly, there were no significant differences in verbal memory $F(1, 37) = 1.17$, $p = .21$, $\eta^2 = .04$, visual memory $F(1, 37) = .05$, $p = .28$, $\eta^2 = .00$, processing speed $F(1, 37) = 0.75$, $p = .39$, $\eta^2 = .02$, reaction time $F(1, 37) = 1.65$, $p = .21$, $\eta^2 = .04$, or total symptoms $F(1, 37) = 0.57$, $p = .46$, $\eta^2 = .02$ between morning and

evening chronotypes. The results from this study suggest that sports medicine professionals can administer CNT before-or after-school depending on their schedule and the athlete's academic and athletic schedule.

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Dedication

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Table of Contents

List of Tables and Figures

Introduction

Approximately 1.6 to 3.8 million sport and recreation-related concussions (SRC) occur annually in the United States (Langlois, Rutland-Brown, & Wald, 2006). Sport-related concussion is a heterogeneous injury that requires a multifaceted assessment and management approach (McCrory et al., 2013). Sport-related concussion management has shifted from relying solely on athletes' subjective, self-reported symptoms (i.e., "Tell me how you are feeling?") to more objective neurocognitive assessments that provide quantifiable data on the current cognitive status of the injured athlete.

Computerized neurocognitive testing (CNT) includes a battery of cognitive tasks, that are derived from traditional paper-and-pencil neuropsychological assessments that measure a wide range of executive functioning including verbal memory, visual design memory, concentration, visual processing speed, and reaction time which are commonly affected following SRC (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009; Makdissi et al., 2001; Schatz, Pardini, Lovell, Collins, & Podell, 2006). Several factors negatively influence CNT performance in non-concussed individuals that include history of concussion (Covassin, Elbin, Kontos, & Larson, 2010), sex (Covassin, Elbin, Harris, Parker, & Kontos, 2012), attention deficit hyperactivity disorder (ADHD), learning disability (LD) (Elbin et al., 2013), sleep (Sufrinko, Johnson, & Henry, 2016), motivation (Bailey, Echemendia, & Arnett, 2006), and physical fatigue (Covassin, Weiss, Powell, & Womack, 2007). Other factors such as cognitive fatigue and time of day may also influence CNT performance. The potential deleterious effects of cognitive fatigue from an academic school day combined with the time of CNT administration (i.e., before or after school) have yet to be examined.

Cognitive fatigue is a common phenomenon, which is the result of sustained cognitive engagement that taxes mental resources (Mullette-Gillman, Leong, & Kurnianingsih, 2015). Previous research has demonstrated that cognitive fatigue leads to burnout, lower motivation, increased distractibility and poor information processing (Boksem, Meijman, & Lorist, 2005, 2006; Demerouti, Bakker, Nachreiner, & Schaufeli, 2001; G. Hockey, John Maule, Clough, & Bdzola, 2000; Holding, 1983; Lorist, Boksem, & Ridderinkhof, 2005; Sanders & Sanders, 2013; van der Linden, Frese, & Meijman, 2003). In a previous study, healthy college students were instructed to perform a task continuously for three hours without rest (Boksem et al., 2005). The students reported an increase in difficulty staying alert and sustaining attention as the three hours elapsed (Boksem et al., 2005). In a more recent study, researchers explored whether cognitive fatigue influences students' performance on a national standardized test (Sievertsen, Gino, & Piovesan, 2016). Students were administered the standardized test at 8:00 AM and were given breaks throughout the day (Sievertsen et al., 2016). The results of the study found that for every hour later in the day, the students' test scores decreased by 0.9% of a standard deviation and after every break performance increased by 1.7% of a standard deviation (Sievertsen et al., 2016). The authors hypothesized that over the course of a school day, students' cognitive resources become taxed and results in fatigue that decreases performance (Sievertsen et al., 2016). These findings suggest that cognitive fatigue may influence cognitive performance after an academic school day. In addition, to cognitive fatigue following a school day, time of day may also influence CNT performance.

Adolescents' cognitive performance may also suffer in the morning hours. At the time of pubertal onset, adolescents tend to have later sleep onset and later wake times (Frey, Balu, Greusing, Rothen, & Cajochen, 2009). This phenomenon can be attributed to two main biological changes in sleep regulation (Carskadon, 2011; Carskadon, Acebo, & Jenni, 2004). First, adolescents' transition from morning-type to evening-type due to changes in circadian phase preference (Frey et al., 2009). The second biological factor is an altered "sleep drive", in which adolescents' pressure to fall asleep accumulates more slowly (Jenni, Achermann, & Carskadon, 2005). In other words, adolescents take longer to fall asleep, leading to later sleep onset. In addition to intrinsic factors such as, puberty, circadian, and homeostatic changes (Dewald, Meijer, Oort, Kerkhof, & Bogels, 2010), adolescents also experience extrinsic factors that contribute to insufficient sleep, like early school times, social pressures, and academic workload (Dewald et al., 2010). These factors have been shown to influence mood, affect regulation, memory, behavior control, executive function and quality of life (Giedd, 2009; Holm et al., 2009; Moore et al., 2009; O'Brien & Mindell, 2005; Pasch, Laska, Lytle, & Moe, 2010; Soffer-Dudek & Shahar, 2011). Although there are many factors that may negatively influence adolescents' cognitive performance throughout the day, such as cognitive fatigue and time of day, circadian arousal patterns may positively influence cognitive performance.

According to circadian arousal pattern, individuals can be described depending on their circadian typology or chronotype (Jovanovski & Bassili, 2007; Randler & Frech, 2006; Roenneberg, Wirz-Justice, & Merrow, 2003). Individuals can be categorized into three different chronotypes, depending on peak arousal: morning, evening, and intermediate types (Fabbri, Mencarelli, Adan, & Natale, 2013; Jovanovski & Bassili, 2007; Rahafar, Maghsudloo, Farhangnia, Vollmer, & Randler, 2016; Randler & Frech, 2006; Roenneberg et al., 2003). Morning-types are individuals who prefer morning activities, get up easily, are more alert in the morning, and go to bed early and wake up early (Preckel et al., 2013; Rahafar et al., 2016). In contrast, evening-types are individuals that prefer afternoon-evening activities, are more alert in the evening, and are able to sleep late in the morning (Preckel et al., 2013). In addition, evening-types are associated with behaviors involving impaired self-regulation, including emotional and behavioral problems (de Souza & Hidalgo, 2014; Diaz-Morales, Escribano, & Jankowski, 2015; Schlarb, Sopp, Ambiel, & Grunwald, 2014; Wang & Chartrand, 2015), substance abuse (Hasler, Sitnick, Shaw, & Forbes, 2013), obesity (Miller, Lumeng, & LeBourgeois, 2015), health risk behaviors (Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002; Malone et al., 2016; Touitou, 2013), and lower school performance (Rahafar et al., 2016; Short, Gradisar, Lack, & Wright, 2013; Tonetti, Fabbri, Filardi, Martoni, & Natale, 2015; Tonetti, Natale, & Randler, 2015). Recent research suggests that an individual's chronotype may influence various cognitive functions such as, attention (Matchock & Mordkoff, 2009), thinking style (Fabbri, Antonietti, Giorgetti, Tonetti, & Natale, 2007), visual search (Natale, Alzani, & Cicogna, 2003), cognitive failure (Mecacci, Righi, & Rocchetti, 2004), intelligence (Goldstein, Hahn, Hasher, Wiprzycka, & Zelazo, 2007; Roberts & Kyllonen, 1999) and academic achievement (Beşoluk, 2011; Digdon & Howell, 2008; Hess, Sherman, & Goodman, 2000; Randler & Frech, 2006, 2009). There is strong evidence to suggest that superior cognitive functioning occurs when testing times are synchronized with individuals' peak circadian arousal periods (i.e., chronotype) (Anderson, Petros, Beckwith, Mitchell, & Fritz, 1991; Petros, Beckwith, & Anderson, 1990). This phenomenon is referred to as the synchrony effect (Anderson et al., 1991; Petros et al., 1990).

Several studies have investigated the synchrony effect in adolescent samples. In a recent study, researchers investigated the influence of a synchrony effect on adolescents' academic performance when administered subtests of the Wechsler Intelligence Scale for Children (WISC-III) (Goldstein et al., 2007; Wechsler, 1991). Participants were assigned to four conditions by crossing chronotype (morning or evening-type) and testing time (morning or afternoon)

(Goldstein et al., 2007). The results of this study revealed a significant synchrony effect for fluid intelligence but no synchrony effect for vocabulary (Goldstein et al., 2007). In addition, researchers examined the effects of testing mode (individual vs. group) and chronotype on academic performance in a sample of adolescents (Clarisse, Le Floc'h, Kindelberger, & Feunteun, 2010). The results of the study reported that morning-type students performed superior in the morning and continued to make progress throughout the day, while evening-type students exhibited poor performance in the morning and improved as the day progressed, eventually matching the morning-type's scores (Clarisse et al., 2010). Although there are several studies that demonstrate the synchrony effect in adolescents, little is known about circadian misalignment and cognition.

Often times concussed high school athletes may still be required to complete an academic school day following a cerebral concussion. Recently, athletic trainers were asked to indicate the frequency of recommending academic accommodations to high school athletes (Kasamatsu, Cleary, Bennett, Howard, & McLeod, 2016). After SRC, 45% percent of athletic trainers recommended complete cognitive rest to high school athletes (Kasamatsu et al., 2016). In addition, athletic trainers recommended a variety of academic accommodations to athletes with SRC (Kasamatsu et al., 2016). Eighty-three percent of athletic trainers recommended postponed schoolwork due dates, 80% recommended rest breaks, and 78% recommended partial school attendance (Kasamatsu et al., 2016). When athletes return to school following SRC, the sports medicine professional is required to work around the athlete's academic schedule when administering concussion assessments that include testing before and/or after school depending on the sports medicine professional, academic, and athletic schedules. Administering CNT after an academic school day may not be the optimal time to evaluate neurocognitive function due to the potential confounding effects of decreased motivation, cognitive fatigue (Boksem et al., 2005; Sievertsen et al., 2016), chronobiology (Horne, Brass, & Pettitt, 1980; Kleitman, 1963; Natale et al., 2003), and fluctuations in circadian rhythm (Benca et al., 2009).

Although, there is growing literature on factors that influence CNT performance, little is known about the potential deleterious effects of cognitive fatigue from an academic school day combined with time of CNT administration (i.e., before, after school). This study will inform baseline and post-concussion testing best practices for sports-medicine professionals who work in the high school setting.

Purpose of the Study

The primary purpose of this study is to compare before-school CNT performance and total symptoms to after-school CNT performance and total symptoms in a sample of non-concussed high school athletes. The secondary purpose of this study is to compare before-school and after-school CNT performance and total symptoms and morning and evening chronotypes in non-concussed high school student athletes.

Hypotheses

Hypothesis 1. After-school neurocognitive performance will be lower and total symptoms will be higher than before-school neurocognitive performance and total symptoms in high school student athletes.

Hypothesis 2. Morning chronotype athletes will demonstrate higher neurocognitive performance and lower total symptoms before-school compared to after-school.

Hypothesis 3. Evening chronotype athletes will demonstrate higher neurocognitive performance and lower total symptoms after-school compared to before-school.

Review of Literature

Sport-related concussion (SRC) continues to be a hot topic in sports medicine. Concussion is defined as a complex pathophysiological process affecting the brain, induced by biomechanical forces (McCrory et al., 2013). 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 et al., 2006). However, this estimate is considered low because many concussions go unrecognized and unreported (Langlois et al., 2006).

Prevalence of Sport-Related Concussion

In a recent epidemiological review, researchers investigated the incidence and injury rates in a nationally representative sample of high school athletes (Gessel, Fields, Collins, Dick, & Comstock, 2007). Of the nine high school sports studied during 2005-2006, 4,431 injuries were reported and 396 (8.9%) were concussions (Gessel et al., 2007). The weighted national estimate for the number of concussions sustained in all sports was 135,901 (Gessel et al., 2007). Of the 396 concussions recorded, 137 (34.6%) occurred in practice and 259 (65.4%) occurred in competition (Gessel et al., 2007). A total of 1,730,764 athletic exposures (AE) were recorded, resulting in a concussion injury rate of 0.23 concussions per 1000 AEs (Gessel et al., 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 et al., 2007).

Previous epidemiological studies reported lower injury rates than this study, however this could be due to an important factor (Powell & Barber-Foss, 1999; Schulz et al., 2004). The higher injury rate may be due to increased awareness of the injury and symptoms as well as better diagnosis and treatment of the injury (Guskiewicz et al., 2006). However, as participation in high school sports continue to increase, the number of concussion will likely increase as well.

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 comes in contact with a solid object (Bailes & Cantu, 2001). Another scenario of linear impact occurs when an athlete's head is stationary and is struck by a moving object (Bailes & Cantu, 2001). Rotational movement occurs when the head is hit at an angle and responds by rotating (Stemper & Pintar, 2014). In recent years, technology has been utilized as a tool to inform sports medicine professionals of 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). 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, Viano, Tucker, Casson, & Waeckerle, 2003). However, data collected from the high school level indicated that 271 impacts exceeded the 70g threshold and 78 impacts exceeded the 98g magnitude with only five reported concussive injuries (Broglio et al., 2009). Another study found no relationship between magnitude of the impact and injury severity measured by decreases in postural control, neurocognitive functioning, and increases in symptom reporting (Guskiewicz et al., 2007). 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, even though high school football games are slower and less physical, resulting in lower impact forces (Broglio et al., 2010; Broglio et al., 2009). 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 & Pintar, 2014).

Pathophysiology of Sport-Related Concussion

Immediately after a direct and/or indirect impact resulting in a cerebral concussion occurs to the brain a series of cellular events referred to as the neurometabolic cascade is set in motion. The neurometabolic cascade describes a complex series of functional and microstructural injury changes that occur after a biomechanical force to the brain (Giza & Hovda, 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 (Barkhoudarian, Hovda, & Giza, 2011; Giza & Hovda, 2001). Immediately after a biomechanical force to the brain, there is an influx of calcium ions and an efflux of potassium ions (Giza & Hovda, 2001). Glutamate binds to the N-methyl-D-aspartate (NMDA) receptor, which leads to further depolarization and an efflux of potassium and an influx of calcium (Giza & Hovda, 2001). In order to restore the neuronal membrane potential the sodium-potassium pump, which requires adenosine triphosphate (ATP), must go into overdrive, requiring more ATP (Giza & Hovda, 2001). This escalation of energy demand increases glucose metabolism into a hypermetabolic state (Giza & Hovda, 2001). In an environment of decreased cerebral blood flow, there becomes a cellular energy crisis results due to a mismatch between energy demand and energy supply (Giza & Hovda, 2001). Post-concussion physiological changes have been shown to increase the brains vulnerability to further injury, making it imperative that the athlete is properly managed to avoid catastrophic injury (Shrey, Griesbach, & Giza, 2011). If a second injury occurs during this vulnerability stage, there could be catastrophic consequences, such as second impact syndrome (Cantu, 1998; Giza & Hovda, 2001).

Signs, Symptoms, and Impairments of Sport-Related Concussion

Sport-related concussion is characterized by a widely variable symptom presentation, meaning that the symptoms vary from athlete to athlete (McCrory et al., 2009). Not all athletes present with the same symptoms and impairments, which make the assessment and management of sport-related concussion difficult. 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 (Collins et al., 2003). Recently, factors, such as, removal from play status (Elbin et al., 2016), on-field dizziness, loss of consciousness, sub-acute post-traumatic migraine and fogginess, have been identified as predictors for protracted recovery (Guskiewicz et al., 2004; Kontos et al., 2013; B. Lau, Lovell, Collins, & Pardini, 2009; B. C. Lau, Kontos, Collins, Mucha, & Lovell, 2011). Specifically, post-concussion 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).

The assessment and management approach for SRC has shifted from relying on athletes' subjective, self-reported symptoms (i.e., "Tell me how you are feeling?") to objective neurocognitive assessments that provide objective quantifiable data on the cognitive status of the injured athlete. The post-concussion symptom assessment relies heavily on the athlete's self-reported symptoms and remains a centerpiece for concussion management. However, athletes tend to withhold and/or minimize their concussion symptoms in hopes to avoid being removed from play or even expedite their return to play (RTP) (McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004; Van Kampen, Lovell, Pardini, 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 an objective complement to athlete symptom reports (Van Kampen et al., 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, attention, visual processing speed, and reaction time which are commonly affected following SRC (Covassin et al., 2009; Makdissi et al., 2001; Schatz et al., 2006). CNT has many advantages compared to traditional paper-and-pencil neuropsychological tests that include: the ability to baseline test groups of athletes concurrently, ease of administration and scoring, alternate test forms to reduce practice effects, and cost effectiveness (Guskiewicz et al., 2004; Woodard & Rahman, 2012).

Current consensus statements recommend, but do not require, neuropsychological baseline testing of athletes pre-season (McCrory et al., 2013). However, CNT is best administered in a prospective manner that involves a pre-season or baseline assessment to allow for comparison to post-concussion performance. Baseline neurocognitive testing provides an accurate representation of the athlete's pre-injury neurocognitive performance and may assist sports medicine professionals on return to play decisions (Covassin et al., 2009; Guskiewicz et al., 2004). In the absence of a baseline assessment, normative data for age and gender are available for post-concussion comparison of scores (Covassin et al., 2009). 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 this assessment.

Factors that Influence Computerized Neurocognitive Testing

Researchers have identified several factors that negatively influence CNT performance. History of concussion has been identified as a factor that influences CNT performance. Athletes with no history of concussion performed significantly better than athletes with a history of three or more concussions on the verbal memory and visual memory composite scores (Covassin et al., 2010). Sex (Covassin et al., 2012) has also been identified as a factor that negatively influences CNT performance. A previous study compared female and male neurocognitive scores on verbal memory, visual memory, visual processing speed, and reaction time. Female athletes preformed worse on visual memory than male athletes (Covassin et al., 2012). A recent study indicated that athletes that report attention deficit hyperactivity disorder (ADHD) and learning disability (LD) diagnosis performed significantly worse on baseline CNT and reported a higher number of symptoms than athletes without LD and/or ADHD (Elbin et al., 2013). Motivation also influences baseline CNT performance. Sub-optimal motivation during baseline testing could lead to an invalid CNT score (Bailey et al., 2006; Bartlett, 1943; Boksem et al., 2005, 2006; R. Hockey, 1983; Meijman, 2000; Sanders & Sanders, 2013; van der Linden et al., 2003). Recently, researchers examined the effects of restricted sleep on CNT performance. Athletes that self-report restricted sleep had worse CNT performance when compared to athletes who self-report optimal sleep (Sufrinko et al., 2016). Lastly, physical fatigue was identified as a factor that influences CNT performance. Athletes that were exposed to maximal exercise immediately before CNT baseline testing performed worse on verbal memory when compared to athletes who rested prior to testing (Covassin et al., 2007). While these factors are all important for the sports medicine professional to consider, the potential combined deleterious effects that cognitive fatigue from the academic setting and time of CNT administration may have 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 athlete's academic schedule, which may influence 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, increased cognitive fatigue following school (Boksem et al., 2005; Sievertsen et al., 2016), chronobiology (Horne et al., 1980; Kleitman, 1963; Natale et al., 2003), and fluctuations in circadian rhythm that occurs during the late afternoon hours (Barnard & Nolan, 2008; Benca et al., 2009; Czeisler & Gooley, 2007).

Cognitive Fatigue and CNT Performance

Cognitive fatigue is the result of sustained cognitive engagement that taxes people's mental resources and is a relatively common phenomenon (Boksem et al., 2005; Mullette-Gillman et al., 2015). Previous research has demonstrated that persistent mental resource burdens result in diminished motivation, increased distractibility, changes in information processing, and poorer mood (Bailey et al., 2006; Bartlett, 1943; Boksem et al., 2005, 2006; R. Hockey, 1983; Meijman, 2000; Sanders & Sanders, 2013; van der Linden et al., 2003). In an early study, pilots were required to fly a simulator for extended periods of time (Bartlett, 1943). The pilots reported periods of decreased attention with increasing frequency and that the operators become more distracted (Bartlett, 1943). In a more recent study, researchers examined the effects of mental fatigue on attention (Boksem et al., 2005). Seventeen healthy college students performed a task continuously for three hours without rest (Boksem et al., 2005). The subjects reported an increase in difficulty staying alert and sustaining attention as the three hours went on (Boksem et al., 2005). In addition, cognitive performance is affected by natural fluctuations in circadian rhythm (Benca et al., 2009).

Cognition and Circadian Rhythm

Circadian rhythms are defined as endogenously driven biological variations that fluctuate with a periodicity of approximately 24 hours and can be synchronized with the external temporal environment by light and nonphonic cues (Benca et al., 2009). 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). Cognition also varies across a 24-hour period (Wright, Lowry, & Lebourgeois, 2012). 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 phase (Wright et al., 2012). Although there is a growing amount of literature suggesting misalignments in circadian rhythm influences cognition in adults, little is still known about misalignments in adolescents. However, several studies suggest that circadian rhythm misalignments in adolescents could have a negative effect on cognitive functioning (Wright et al., 2012).

In an early study researchers examined the effects of early school start time on adolescent sleep patterns, sleepiness, and circadian phase (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998). Early school start time was associated with sleep deprivation and daytime sleepiness (Carskadon et al., 1998). According to the US Department of Education (2011-2012), approximately 43% of all public high schools in the United States start school before 8:00 AM. The early start time requires adolescents to perform at a certain cognitive level before the waking-promoting effects of the circadian system are fully engaged (Carskadon et al., 1998). Second, executive 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). However, Sievertsen and colleagues (2016) explored whether cognitive fatigue influences students' performance on a national standardized test (Sievertsen et al., 2016). Students were administered the test at 8:00 AM and were given breaks throughout the day (Sievertsen et al., 2016). The results of the study found that for every hour later in the day, the students' test scores decreased by 0.9% of a standard deviation and after every break performance increased by 1.7% of a standard deviation (Sievertsen et al., 2016). The authors hypothesized that over the course of a school day, students' cognitive resources become taxed, increasing fatigue and ultimately decreasing performance (Sievertsen et al., 2016). These findings suggest that fatigue may influence cognitive performance throughout the day.

Sleep, Circadian Rhythm, and Cognitive Function

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). The intention of the circadian process is for wakefulness to take place during the day and sleep to take place at night (Schmidt et al., 2007). Multiple studies show that effects of shortened sleep on daytime functioning include sleepiness, tiredness, difficulty waking, moodiness, and diminished attention difficulties in school (Carskadon, Vieira, & Acebo, 1993; Epstein, Chillag, & Lavie, 1998).

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 et al., 1992). However, when wakefulness was extended, alertness and performance decreased significantly (Dijk et al., 1992). In a more recent study, researchers investigated the relationship between sleep duration and academic performance, daytime tiredness, behavioral persistence and positive attitude towards life (Perkinson-Gloor, Lemola, & Grob, 2013). These findings are particularly interesting when looking at the sleeping habits of adolescents. In a recent poll, the National Sleep Foundation found that 87% of high school students in the United States get less than the recommended 8.5 to 9.5 hours of sleep on a school night. Insufficient sleep in adolescents may be the result of an interaction of intrinsic (e.g. puberty, circadian or homeostatic changes) and extrinsic (e.g. early school times, social pressure, academic workload) factors (Dewald et al., 2010).

Morningness Versus Eveningness Chronotypes

According to circadian arousal pattern, in chronopsychology and chronobiology, individuals can be described depending on their circadian typology or chronotype (Jovanovski &

Bassili, 2007; Randler & Frech, 2006; Roenneberg et al., 2003). Max arousal can be reached either in the morning or in the evening, according to circadian typology (Fabbri et al., 2013). 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; Duffy, Dijk, Hall, & Czeisler, 1999; Horne & Ostberg, 1976).

The two chronotypes, morning-types and evening-types, differ in cognitive efficiency during the day (Horne et al., 1980; Natale et al., 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 et al., 1991; Petros et al., 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; M. Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1998; M. J. Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1999; May & Hasher, 1998; May, Hasher, & Foong, 2005; May, Hasher, & Stoltzfus, 1993; Rowe, Hasher, & Turcotte, 2009; Yang, Hasher, & Wilson, 2007).

Methods

Research Design

A crossover design will be used to compare differences in CNT performance and total symptoms between before-school and after-school testing sessions

Participants

Thirty-nine non-concussed high school athletes currently participating in the University of Arkansas Sport Concussion Surveillance Program were recruited to participate. Athletes that reported previous diagnosed learning disability (LD), attention deficit hyperactivity disorder (ADHD), endorsed English as a second language, were diagnosed with a concussion within six months of recruitment, reported not being tired after an academic school day and reported not having a difficult academic schedule were excluded from the study.

Measures/Instrumentation

Main outcome measures and measures to control for confounding variables. The main outcome measure used in this study was Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) and the Post-Concussion Symptom Scale (PCSS). In addition, the Morningness-Eveningness Questionnaire (MEQ-SA) was used as a main outcome measure. Additionally, in order to control for potential confounding variables, the Effort Form, Pittsburgh Sleep Quality Index-per week, Food Intake Form, and Cognitive Demand of School Form were used.

Demographics. Demographic data including age, sex, previous number of diagnosed concussions, and hours of sleep were obtained from the demographic section of ImPACT. In addition hours of sleep within the past week was obtained from the Pittsburgh Sleep Quality Index-per week. Diet information was obtained by the Food Intake form. Participants self-reported fatigue before-and after-school was obtained by the Visual Analogue Scale – Fatigue and effort was obtained by the Effort Form.

Recruitment form. The recruitment form is a short questionnaire created by researchers that consisted of inclusion and exclusion criteria for the study. This short form (See Appendix A) was given in large groups to all possible participants. In order to be selected for study, participants were required to have transportation to their high school at 7:00AM, report an academic difficulty of class schedule of a three or higher, on a five point Likert scale (1 = not difficult, 5 = extremely difficult), and report perceived tiredness after a full day of school of a three or higher, on a five point Likert scale (1 = not tired at all, 5 = extremely tired). Lastly, all potential participants were required to report English as their first language, no history of LD, or ADHD and no diagnosed concussion within the last six months.

Neurocognitive performance. CNT performance was measured using the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery. The ImPACT test is comprised of three sections: demographic information, the Post-Concussion Symptom Scale (PCSS) and neurocognitive test modules (Elbin et al., 2013). The ImPACT battery takes approximately 25 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, 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 0.62 to 0.88 for outcome scores (Iverson, Lovell, & Collins, 2005). ImPACT also assesses current symptom reports via the Post-Concussion Symptoms Scale (PCSS), which is a 22-item, 7-point Likert symptom inventory. The reliability and validity of the PCSS have been well documented in previous studies (Lovell et al., 2006). In order to investigate baseline and post-concussion symptoms more thoroughly, symptoms on the PCSS can be analyzed in clusters (Kontos et al., 2012). There are four baseline clusters: cognitive-sensory (e.g., sensitivity to light, difficulty concentrating), sleep-arousal (e.g., drowsiness, sleeping less than usual), vestibular-somatic (e.g., headache, dizziness), and affective (e.g., sadness, nervousness). In addition, there are four post-concussion factors: 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).

Morningness/Eveningness questionnaire (MEQ-SA). The MEQ-SA was used in this study to as a main outcome measure. The MEQ-SA is comprised of sleep-related questions to determine and evaluate circadian rhythm patterns. The questionnaire contains 19 questions that examine sleep habits and fatigue. After completion of the questionnaire, the score can be calculated by adding the number of points of each question. The points can range from 16 to 86. Scores 41 and below indicate “evening-types”, while scores 59 and above indicate “morning-types”. Scores between 42 and 58 indicate “intermediate-types”. The reliability and validity of the MEQ-SA have been well documented in previous studies (Horne & Ostberg, 1976). In addition, Natale and colleagues (2002), further divided the “intermediate type” into two categories: intermediate morning and intermediate evening. With the addition of these two types, the MEQ-SA can be analyzed using six categories: definitely morning (70-86), moderately morning (59-69), intermediate-morning (50-58), intermediate-evening (42-49), moderately evening (31-41) and definitely evening (16-30) (Natale & Cicogna, 2002). See Appendix B.

Fatigue assessment. The Visual Analogue Scale – Fatigue (VAS-F) was used to assess self-reported fatigue. The VAS-F is comprised of an 18-item, 10-point Likert scale ranging from

0 (“not at all tired”) to 10 (“extremely tired”). The VAS-F consists of two subscales: fatigue and energy. The fatigue subscale is calculated by averaging corresponding fatigue items and the energy subscale is calculated by averaging the corresponding energy items. Previous research has presented self-reported fatigue and energy, from the VAS-F, as means across time (Lee, Hicks, & Nino-Murcia, 1991). The VAS-F is a valid and reliable tool previously used to asses fatigue in healthy and sleep deprived individuals (Lee et al., 1991). Specifically, the fatigue subscale of the VAS-F has demonstrated acceptable reliability in healthy individuals with a Cronbach's $\alpha = 0.91$ in the evening and Cronbach's $\alpha = 0.96$ in the morning. The energy subscale of the VAS-F has demonstrated acceptable reliability in healthy individuals with a Cronbach's $\alpha = 0.94$ in the evening and Cronbach's $\alpha = 0.95$ in the morning (Lee et al., 1991). See Appendix C.

Pittsburgh sleep-quality index per week (PSQI-pw). The PSQI-pw was used in this study to examine sleep quality. The PSQI-pw is comprised of 10 questions that examine sleep patterns and sleep quality of the previous week. The PSQI has a sensitivity of 89.6% and specificity of 86.5% (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). See Appendix D.

Food intake form. The Food Intake Form was created by researchers. The Food Intake Form was used to obtain dietary information about the participants. This survey consists of four questions that ask the participants to indicate what they ate for breakfast and lunch, caffeine consumed, and supplements consumed before CNT administration. The Food Intake Form was administered to quantify food and caffeine consumption and to control for confounding factors that may influence CNT performance and symptoms. See Appendix E.

Effort form. The Effort Form is a short survey created by researchers to quantify effort immediately after completion of CNT. The participants were asked to indicate the amount of effort they gave while completing CNT. The effort form consists of one question and is scaled using a 4-point Likert scale (1 = "No effort" to 4 = "High effort"). See Appendix F.

Cognitive demand of school intake form. The Cognitive Demand of School Intake Form, developed by the researchers, was used in this study to quantify perceived academic difficulty. The Cognitive Demand of School Intake Form consists of three questions. The form asked participants to report the number of classes in their academic schedule, specifically the number of advanced placement (AP) classes, pre-advanced placement (Pre-AP) and elective classes in their schedule. In addition the form asked participants to indicate the perceived difficulty of their academic school day on a five point Likert scale (1 = "not at all difficult" to 5 = "extremely difficult"). See Appendix G.

Procedures

Upon obtaining University IRB approval (See Appendix H), researchers recruited 183 non-concussed high school student athletes participating in the U of A Sport Concussion Surveillance Program using the Recruitment Form. The Recruitment Form was administered to all potential participants interested in participating in the study. After all potential participants completed the Recruitment Form, trained researchers confirmed inclusion and exclusion criteria via Recruitment Form. Participants that did not meet all inclusion and exclusion criteria were dismissed and participants that met inclusion and exclusion criteria were read the consent form and formally invited to participate in the study.

After receiving parental consent and child assent, the participants were randomly and conveniently assigned into either a before-school/after-school (n = 18) testing order or an after-school/before-school (n = 21) testing order. Four (10%) athletes were conveniently assigned to a testing order, because they participated in multiple sports during the time period of this study.

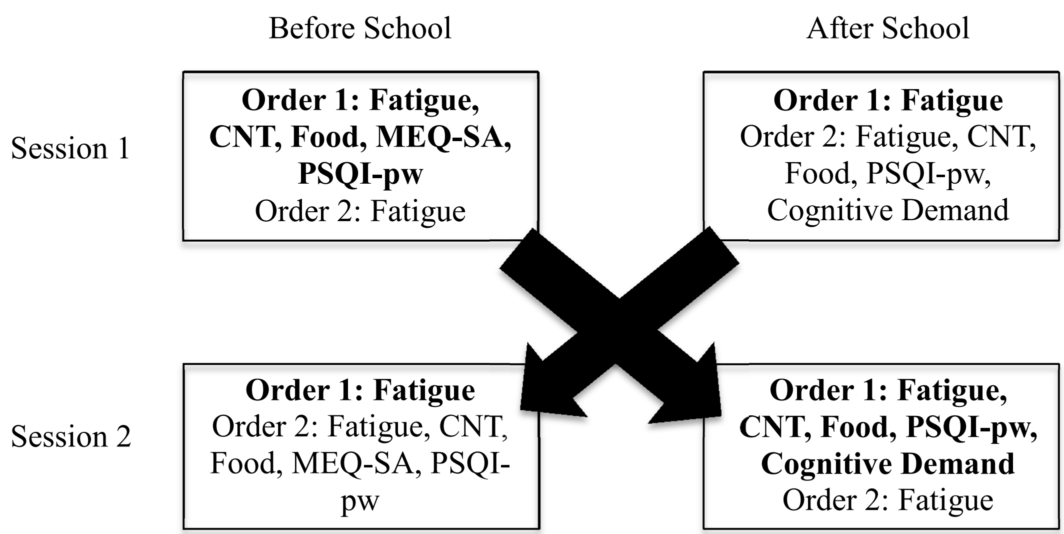
These athletes were assigned accordingly to accommodate for practices and games of their current sport. Fifteen (38%) athletes were also conveniently assigned to a testing order depending on the hour of their athletics period. The remaining 20 (51%) athletes were randomly assigned to a testing order.

The participants were administered the VAS-F, ImPACT, Effort Form, Food Intake Form, MEQ-SA, and PSQI-pw during the before-school testing session. During the after-school testing session participants were administered the VAS-F, ImPACT, the Effort Form, Food Intake Form, PSQI-pw, and Cognitive Demand of School Intake Form. The before-and after-school testing sessions, in which these measures were administered, took place approximately in the middle of the week (Wednesday/Thursday). In addition, there was approximately one week separation between the before-school testing session and the after-school testing session.

All participants completed these measures in the high school's designated computer lab at their assigned before-school or after-school order. All participants completed the ImPACT battery in supervised groups of 10 to 15 students. Upon completion of this visit the athletes reported for their final testing session to complete the measures the following week in opposite condition (before, after-school) (i.e., cross-over design). For example, participants assigned to the before-school/after-school testing order, completed the VAS-F, ImPACT, Effort Form, Food Intake Form, MEQ-SA, and PSQI-pw at approximately 7:00AM before-school. One week later, participants completed the VAS-F, ImPACT, Effort Form, Food Intake Form, PSQI-pw, and Cognitive Demand of School Intake Form at approximately 3:00PM after-school. In addition, when participants were not administered the outcome measures described above, they were still required to complete the VAS-F. For example, participants assigned to the before-school/after-school testing order completed the VAS-F, ImPACT, Effort Form, Food Intake Form, MEQ-SA, and PSQI-pw at approximately 7:00AM before-school and completed the VAS-F at approximately 3:00PM after-school on the same day. Approximately one week later the participants completed the VAS-F at approximately 7:00AM before-school and completed the VAS-F, ImPACT, Effort Form, Food Intake Form, PSQI-pw, and Cognitive Demand of School Intake Form at approximately 3:00PM after-school on the same day. A graphic figure depicting the cross-over design is presented in Figure 1.

Figure 1.

Representation of cross-over design and administration order of study measures.



In an effort to mitigate poor effort when completing the neurocognitive battery, the current study used deception via an instructional script (See Appendix I). Specifically, participants were told that compensation for the study depended on their effort and performance on the CNT (i.e., higher effort and scores will equate to maximum cash prize). However, all participants who completed both the before-school and after-school testing sessions received the 40 dollar cash prize, regardless of their effort. Participants did not receive remuneration until after the completion of their second session.

Data Analysis

Descriptive statistics (e.g., means and standard deviations) were used to describe sample demographics (e.g., age, sex, history of concussion). In addition, data from the VAS-F, Effort Form, PSQI-pw, and Food Intake Form were analyzed in order to control for various confounding variables (i.e., fatigue, effort, diet, and sleep). Statistical analyses were conducted using SPSS.

Controlling for effort, sleep, and diet among the before-and after-school testing sessions. In order to control for potential confounding variables all participants were administered the Effort Form, Food Intake Form, and PSQI-pw immediately after completing ImPACT at both before-and after-school testing sessions. These measures were used in order to gather information on potential confounding factors that could influence ImPACT performance. A series of paired samples t-tests were conducted in order to control for various confounding variables (i.e., sleep, effort) and to examine differences on these variables between the two-time points (before, after school). Statistical significance was set at a Bonferroni corrected $p \leq .01$. In addition, a series of Chi-square tests were conducted to ensure equivalency of dietary consumption between the before-and after-school testing sessions.

Preliminary analysis of study assumption – High school student athletes will report higher fatigue after-school than before-school. The assumption that high school student athletes will be more fatigued after-school than before-school was examined with a repeated measures ANOVA. A repeated measures ANOVA was conducted in order to investigate changes in self-reported fatigue of all athletes at four time points. The independent variable was time, which consisted of four levels (before-and after-school on testing session one and before-and after-school on testing session two), and the dependent variable was VAS-F self-reported fatigue. Statistical significance was set at a Bonferroni corrected $p \leq .01$.

Data analysis for H1 – After-school neurocognitive performance will be lower and total symptoms will be higher than before-school neurocognitive performance and total symptoms in high school student athletes. Hypothesis 1 was examined with a series of paired samples t-tests. The independent variable was time (i.e., before, after-school) and dependent variables were ImPACT composite scores of verbal memory, visual memory, 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 $p \leq .01$.

Data analyses for H2 and H3 – Morning chronotypes will demonstrate higher before-school neurocognitive performance and lower total symptoms than after-school neurocognitive performance (H2) and Evening chronotypes will demonstrate higher after-school neurocognitive performance and lower total symptoms than before-school neurocognitive performance (H3). Using the method Natale and colleagues (2002) applied, participants were categorized into six categories: definitely morning, moderate morning, intermediate morning, intermediate evening, moderate evening, and definitely evening. However, due to little variability between the six categories, definitely morning, moderate morning, and intermediate morning were combined to make one morning-type group, and definitely evening, moderate evening, and intermediate evening were combined to make one evening-group. Hypothesis 2 and 3 were analyzed using a series of 2 group (morning, evening-type) x 2 time (before, after school) repeated measures within/between groups ANOVAs. The independent variables were time (before, after-school) and group (morning, evening-type), with time being the within-subjects factor and group being the between-groups factor. The dependent variables were ImPACT composite scores of verbal memory, visual memory, processing speed, and reaction time**.** In addition, PCSS total symptom score was also used as a dependent variable. Statistical significance was set at a Bonferonni corrected $p \leq .01$.

Results

Participant Recruitment Results

A total of 183 athletes were screened for participation in the study. Fifty-nine percent (108/183) of the screened sample did not meet one or more of the following exclusion criteria and were not asked to participate in the study: endorsed English as a second language, reported a diagnosis of LD and/or ADHD, sustained a concussion within six months of the recruitment period, reported not being tired at the end of the academic school day, or reported that their academic schedule was not difficult. Seventy-six athletes met inclusion criteria and were enrolled in the study. However, 37 of the recruited athletes did not complete all testing sessions yielding an attrition rate of 49% (37/76).

Demographics of the Final Sample

The final sample included a total of 39 (39/76) non-concussed high school athletes, yielding a response rate of 51%. There were 34 males and 5 females in this sample, and the average age was 15.74 ± 1.04 (Range = 14 – 18) years. These athletes were current participants in football 64% (25/39), basketball 33% (13/39) and track and field 3% (1/39). The average number of previous concussions for the final sample was 0.26 (*SD* = 0.55; Range = 0 – 2). There was approximately one week (*M* = 7.10, *SD* = 0.31) between the two testing sessions. Information obtained during the recruitment of these athletes regarding self-reported perceived academic difficulty and tiredness after school are presented in Table 1.

Table 1.

Means and standard deviations of demographic variables of the total sample (N = 39)

	M	*SD*
Age (yrs.)	15.74	1.04
Concussion History	0.26	0.55
Perceived academic difficulty	3.28	0.51
Perceived tiredness after school	3.69	0.61

* $p \leq .05$

Controlling the effects of effort, sleep, and diet among the before-and after-school testing sessions. There were no significant differences between hours of sleep $t(38) = 0.37$, $p = .71$, or effort $t(38) = 0.57$, $p = .57$, between the before-and after-school time points. Means and standard deviations of hours of sleep and effort given during the before-and after-school testing sessions are presented in Table 2.

Table 2.

Means and standard deviations of effort and hours of sleep between before-school and after-school testing sessions (N = 39)

		M	*SD*
Before-School Session			
	Effort	3.95	0.22
	Hours of Sleep	7.45	1.05
After-School Session			
	Effort	3.92	0.27
	Hours of Sleep	7.38	1.68

* $p \leq .05$

The Chi-square test for independence (with Yates Continuity Correction) indicated no significant association between breakfast consumption between before-school and after-school testing sessions χ^2 (1, $n = 39$) = 2.53, $p = .11$, phi = .32. A Chi-square test for caffeine consumption was inappropriate due to the low frequency of participants who reported consuming caffeine before each testing session. The minimum requirement count is five to run a Chi-square. Frequencies of breakfast, lunch, and caffeine consumption are presented in Table 3.

Table 3.

Frequency of breakfast, lunch, and caffeine consumption before taking ImPACT *before-school and after-school for the total sample (N = 39)*

		n	%
Before-School Session			
	Breakfast	17	44%
	Caffeine	3	8%
After-School Session			
	Breakfast	31	80%
	Lunch	39	100%
	Caffeine	6	15%

* $p \leq .05$

Preliminary analysis – Examining self-reported fatigue before-and after-school. In order to investigate the hypothesis that after school ImPACT performance and symptoms would be worse than before-school ImPACT performance and symptoms, an assumption was made that high school student athletes would be more fatigued after-school than before-school. Self-reported fatigue was measured at four time points and there was no significant main effect for time for fatigue $F\ (3, 36) = 3.85$, $p = .02$, $\eta^2 = .24$. Information regarding changes in self-reported fatigue before and after school at four time points are presented in Table 4.

Table 4.

Analysis of self-reported fatigue across four time points for the total sample (N = 39)

	Time Point 1 – Before-School		Time Point 2 – After-School		Time Point 3 – Before-School		Time Point 4 – After-School	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Fatigue	3.74	1.62	3.30	2.07	3.91	2.13	2.82	2.06

*$p \leq .01$

A different approach to investigating fatigue was also conducted. Self-reported fatigue at both before-school time points (i.e., time point 1 and 3 on Table 4) were averaged together as well as both after-school time points (i.e., time point 2 and 4 on Table 4). A paired samples t-test was conducted in order to compare before-school average self-reported fatigue to after-school average self-reported fatigue. Before-school fatigue was significantly greater than after-school fatigue ($t(38) = 2.84$, $p = .007$). Means and standard deviations of the average self-reported fatigue between before-school and after-school are presented in Table 5. These findings prompted further exploratory investigations of fatigue used as an independent variable and are presented in the Supplemental Analyses section.

Table 5.

Analysis of before-school self-reported fatigue and after-school self-reported fatigue of total sample (N = 39)

	Before-School		After-School	
	M	*SD*	*M*	*SD*
Self-Reported Fatigue *	3.83	1.64	3.06	1.91

* $p \leq .01$

Evaluation of Hypotheses

Hypothesis 1 – After-school neurocognitive performance will be lower and total symptoms will be higher than before-school neurocognitive performance in high school student athletes. The results of a series of paired sample t-tests yielded no significant differences in verbal memory $t(38) = 0.80$, $p = .43$, visual memory $t(38) = -0.78$, $p = .44$, processing speed $t(38) = .07$, $p = .94$, reaction time $t(38) = 1.45$, $p = .16$, or total symptoms $t(38) = -0.64$, $p = .52$. Means and standard deviations for these outcome variables are presented in Table 6.

Table 6.

Analysis of before-and after-school ImPACT performance and total symptoms (N = 39)

	Before-School		After-School	
	M	*SD*	*M*	*SD*
Verbal Memory	88.43	9.39	87.03	10.67
Visual Memory	79.62	13.43	81.21	11.09
Processing Speed	39.83	6.61	39.77	5.70
Reaction Time	0.59	.06	0.58	.07
Total Symptoms	6.56	7.13	7.15	6.73

$^*p \leq .01$

Hypothesis 2 – Early chronotype athletes will demonstrate higher neurocognitive performance and lower total symptoms before-school compared to after-school. Hypothesis 3 – Late chronotype athletes will demonstrate higher neurocognitive performance and lower total symptoms after-school compared to before-school. Initially there were 3/39 (8%) morning-types, 35/39 (89%) intermediate-types, and 1/39 (3%) evening-types. After applying the method utilized by Natale and colleagues (2002), there were 15/39 (38%) morning-types and 24/39 evening-types (62%) in the final sample. There were 22 males and 2 females categorized as evening-type and there were 12 males and 3 females categorized as morning-type. The results of the 2 group (morning, evening-type) x 2 time (before, after-school) repeated measures ANOVAs revealed no significant group x time interaction for verbal F (1, 37) = 1.60, p = .21, η^2 = .04, visual F (1, 37) = .05, p = .82, η^2 = .00, processing speed F (1, 37) = 0.75, p = .39, η^2 = 0.02, reaction time F (1, 37) = 1.65, p = .21, η^2 = 0.04, and total symptom score F (1, 37) = 0.57, p = .46, η^2 = 0.02. In addition, there was no significant main effect for group for verbal F (1, 37) = .03, p = .86, η^2 = .00, visual F (1, 37) = 0.22, p = .64, η^2 = .01, processing speed F (1, 37) = 1.25, p = .27, η^2 = .03, reaction time F (1, 37) = .05, p = .83, η^2 = .00, and total symptoms F (1, 37) = 0.52, p = .48, η^2 = 0.01 as well as no significant main effect for time for verbal F (1, 37) = 1.17, p = .29, η^2 = .03, visual F (1, 37) = 0.50, p = .49, η^2 = 0.01, processing speed F (1, 37) =

.02, *p* = .90, η^2 = .00, reaction time *F* (1, 37) = 2.95, *p* = .10, η^2 = .07, and total symptoms *F* (1, 37) = 0.64, *p* = .43, η^2 = 0.02. Means and standard deviations of ImPACT composite scores and total symptoms between the two groups (i.e., morning and evening chronotypes) are presented in Table 7.

Table 7.

Means and standard deviations of ImPACT composite scores and total symptoms of morning (n = 15) and evening (n = 23) chronotypes

	Morning-Type				Evening-Type			
	Before-School		After-School		Before-School		After-School	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Verbal Memory	90.13	8.77	85.93	9.40	87.38	9.79	87.71	11.53
Visual Memory	80.93	11.74	81.93	11.31	78.79	14.57	80.75	11.16
Processing Speed	40.62	4.32	41.49	4.98	39.34	7.76	38.69	5.95
Reaction Time	0.59	.05	0.57	.07	0.59	.06	0.58	.07
Total Symptoms	5.20	6.83	6.67	6.28	7.42	7.32	7.46	7.12

*$p \leq .01$

Discussion

General Discussion of Results

This study compared before-school neurocognitive performance and total symptoms to after-school neurocognitive performance and total symptoms in a sample of non-concussed high school athletes. The primary finding from this study was that before-school neurocognitive performance and total symptoms did not differ from after-school neurocognitive performance and total symptoms. This finding suggests that sports medicine professionals can administer CNT before-or after-school without fear of the confounding effects of time or cognitive fatigue from an academic school day. The secondary finding of this study was that morning-type CNT performance and total symptoms did not differ between before-and after-school and evening-type CNT performance and total symptoms did not differ between before-and after-school.

Preliminary Analysis – Examining Self-Reported Fatigue Before-and After-School.

Based on previous literature, an assumption was made that high school athletes would be more fatigued after-school than before-school. The result of this fatigue from an academic school day could decrease neurocognitive performance and increase symptoms. Cognitive fatigue has been shown to lead to diminished motivation, increased distractibility, changes in information processing and poorer mood (Boksem et al., 2005, 2006; Demerouti et al., 2001; G. Hockey et al., 2000; Holding, 1983; Lorist et al., 2005; Sanders & Sanders, 2013; van der Linden et al., 2003). In addition, a recent study similar to the current study, reported worse performance on a standardized test as the day progressed (i.e., got later in the day) in high school students (Sievertsen et al., 2016). The authors hypothesized that performance decreases as cognitive resources get taxed (Sievertsen et al., 2016). However, this assumption was not corroborated in this study. Before-school self-reported fatigue was significantly higher than after-school self-reported fatigue. Although this finding is unexpected, there could be several explanations for this finding.

Insufficient sleep (i.e., less than 8 hours per night) has increasingly become the norm for the adolescent (i.e., high school aged) population (Eaton et al., 2010; National Sleep Foundation). Athletes that participated in this study reported getting less than 8 hours of sleep recommended for adolescents. This could be due to several factors. At the time of puberty adolescents experience a sleep-wake "phase delay" (i.e., later sleep onset and wake times) (Au et al., 2014). Adolescents go to sleep at later times and tend to wake up at later times. In fact, many adolescents use the weekends to "catch up" on sleep missed throughout the week (Au et al., 2014). Consequently, this method of catching up on sleep can worsen circadian disruption and can lead to morning sleepiness at school (Dahl & Carskadon, 1995; Fredriksen, Rhodes, Reddy, & Way, 2004; Jenni et al., 2005). In addition to early school times, increased social pressures and academic workload may contribute to insufficient sleep while in high school (Dewald et al., 2010). Lastly, this finding (i.e., before-school self-reported fatigue higher than after-school self-reported fatigue) could be due to the fact that adolescents shift in circadian phase preference from morning type to evening type, which could result in later bed times (Frey et al., 2009). Also, adolescents take longer to fall asleep at night due to an altered sleep drive (Jenni et al., 2005). Therefore, the athletes in the current may have been more fatigued before-school than after-school due to insufficient sleep due to biologic changes as well as early start times.

Discussion of Hypotheses

Hypothesis 1 – After-school neurocognitive performance will be lower and total symptoms will be higher than before-school neurocognitive performance in high school student athletes. Due to the main findings of this study, Hypothesis 1 was not supported. There could be several possible explanations for the lack of differences between before-and after-school neurocognitive performance and total symptoms. Again, previous research suggests cognitive engagement taxes individuals' mental resources leading to cognitive fatigue (Boksem et al., 2005; Mullette-Gillman et al., 2015). At the same time, as discussed above, high school students oftentimes do not get 8.5 to 9.5 hours of sleep (National Sleep Foundation) that is recommended for adolescents. In fact, athletes that participated in this study reported getting an average of 7.45 and 7.38 hours of sleep before each testing session, which is less than the recommended amount for adolescents. This combination of cognitive fatigue and insufficient sleep could potentially "even out" these influences, eliminating any differences between before- and after-school neurocognitive performance and symptoms. However, more research is needed on this subject to further understand the differences in neurocognitive performance and total symptoms before-and after-school.

Hypothesis 2 and 3 – Morning chronotypes will demonstrate higher before-school neurocognitive performance and lower total symptoms than after-school neurocognitive performance (H2) and Evening chronotypes will demonstrate higher after-school neurocognitive performance and lower total symptoms than before-school neurocognitive performance (H3). Before applying the method used by Natale and colleagues (2002) (i.e., splitting the intermediate-type athletes into intermediate-morning and intermediate-evening), athletes in the current study were categorized as more intermediate-type than morning and evening-types. This finding has also been documented in previous studies identifying chronotypes in adolescent-aged and college-aged populations. In a previous study, researchers identified morningness and eveningness existed on a continuum between the two extremes in a college-aged population (Natale & Cicogna, 2002). The two extreme typologies (i.e., morning and evening) did not include a large number of individuals, in fact only about 10% of the population falls within the two extreme categories (Natale & Cicogna, 2002). In addition, this study suggests that most individuals (60-70%) fall within the intermediate type (Natale & Cicogna, 2002). This distribution was again identified in a recent study by Urbán and colleagues (2011) estimating the distribution of chronotype (i.e., morning, intermediate, evening) in an adolescent population. The authors identified 50.7% of the sample as intermediate type, 30.5% as morning type, and 18.8% as evening type (Urbán et al., 2011). There is reason that could explain the finding of no synchrony effect in the final sample. As explained above, only a small percentage of the population is categorized as the two extreme chronotypes: morning-type or evening-type (Natale & Cicogna, 2002). In addition, the MEQ-SA is a self-reported measure, so although the athletes in this study were categorized as morning-type and evening-type for the purpose of this study, these athletes could truly be intermediate-types.

Discussion of Supplementary Analyses

One interesting finding from the supplementary analysis is that athletes who reported being fatigued after-school did not perform significantly worse or report more symptoms than athletes who did not report being fatigued after-school. This finding suggests that self-reported fatigue does not influence CNT performance or symptoms. One reason for this could be that an academic school day does not make high school athletes cognitively tired and does not constitute as a cognitively fatiguing activity. The previous study exploring how fatigue influences test scores has used standardized tests of reading, math and various sciences (i.e., geography, physics, chemistry and biology) to fatigue the students (Sievertsen et al., 2016).

Implications

Many times, post-concussion CNT is administered before-or after-school depending on the sports medicine professional's schedule as well as the athlete's academic and athletic schedule. The results of this study suggest sports medicine professionals can administer CNT before-or after-school without concern of confounding factors, like time of day or cognitive fatigue, influencing CNT performance or symptoms.

Limitations

There are several limitations to this study. First, many measures (i.e., demographic, VAS-F, PSQI-pw, MEQ-SA, Food Intake Form, Effort Form, Cognitive Demand of School Intake Form) used in this study were self-reported by athletes. It is assumed that athletes reported honestly on all self-reported measures. Second, the same test version was given a both testing sessions, which may result in some learning effects because some stimuli are only reordered (Schatz et al., 2014). Third, the athletes that participated in this study were from three different schools. Lastly, the sample size was relatively small. After running a post-hoc power analysis to determine an appropriate sample size for the paired samples *t*-test a sample size of over 100 is needed.

Future Research

Future research should continue to explore the effects of cognitive fatigue and time of CNT administration on CNT performance and symptoms. An increase in sample size is needed to further understand how these potentially confounding factors could influence performance and symptoms. In addition, a larger sample size may result in an observed synchrony effect in morning types and evening types. Lastly, future research should investigate effects of cognitive fatigue and time of CNT administration on CNT performance and symptoms in college-aged athletes. The transition from high school student to college student is characterized by a shift in personal responsibilities, decreased institutional support, and changes in social environment (Astin, 1984; Evans, 2009; Schulenberg, Sameroff, & Cicchetti, 2004). This transition period could influence regulation, which could affect CNT performance.

Conclusions

The results of this study did not support the hypothesis that after-school neurocognitive performance and total symptoms would be worse than before-school neurocognitive performance and symptoms. In addition, there was no synchrony effect observed for morning types or evening types before-or after-school. The results of the current study suggest that sports medicine professionals can administer CNT before-or after-school without concern of confounding factors influencing performance and symptoms.

Supplemental Analyses

Table 8.

Supplemental Analyses of Results

Question	Exploratory Analysis Performed
Are there differences in ImPACT symptom clusters before-and after-school?	Paired samples t-tests (Non Significant) See Table 9.
Does self-reported fatigue change before-and after-school ("Do athletes get more fatigued from school?")?	Paired samples t-test (Non Significant) See Table 10.
Does self-reported energy levels change across time?	Repeated measures ANOVA (Significant main effect for time) See Table 11.
Does self-reported energy levels change before-and after-school ("Do athletes get less energized from school?")?	Paired samples t-test (Significant) See Table 12.
Is there a relationship between before-school self-reported fatigue and energy between the two testing sessions ("Are self-reported fatigue and energy after school consistent across the two sessions?")?	Spearman correlation (Significant and non significant) See Table 13 and 14.
Is there a relationship between after-school self-reported fatigue and energy between the two testing sessions (Are self-reported fatigue and energy after school consistent across the two sessions?")?	Spearman correlation (Significant) See Table 15 and 16.
Is there a relationship between PCSS fatigue and VAS-F self-reported fatigue before and after school ("Is fatigue reported on the PCSS and VAS-F related before-and after-school?")?	Spearman correlation (Significant and non significant) See Table 17.
Is there a difference between ImPACT composite scores and total symptoms between athletes who took ImPACT before-school first and athletes who took ImPACT after-school first?	Independent samples t-test (Non Significant) See Table 18.
Are there differences in ImPACT composite scores and total symptoms in athletes that are and are not fatigued by school the first time they take ImPACT?	Independent samples t-test (Non significant) See Table 19.

Table 8.

Supplemental Analyses of Results (Cont.)

Question	Exploratory Analyses Performed
Are there differences in PCSS baseline symptom clusters in athletes that are and are not fatigued by school the first time they take ImPACT?	Independent samples t-test (Significant) See Table 20.

Table 9.

Analysis of PCSS baseline symptom clusters before-and after-school (N = 30)

	Before-School		After-School	
	M	*SD*	*M*	*SD*
Cognitive-Sensory	1.36	2.11	1.64	1.95
Sleep-Arousal	3.00	3.32	3.13	3.17
Vestibular-Somatic	0.72	1.72	0.64	1.51
Affective	0.92	1.93	1.26	2.14

* $p \leq .01$

Table 10.

Analysis of change in self-reported fatigue between Week 1 and Week 2 (N = 39)

	Week 1		Week 2	
	M	*SD*	*M*	*SD*
Change in Self-Reported Fatigue	0.44	1.96	1.09	2.19

* $p \leq .05$

Table 11.

Analysis of self-reported energy across four time points (N = 39)

	Time Point 1 – Before-School		Time Point 2 – After-School $_c$		Time Point 3 – Before-School $_a$		Time Point 4 – After-School $_c$	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Energy	5.39	1.38	5.56	1.78	4.30	1.25	5.73	1.87

$_a$ significantly different from Time Point 1, $_b$ significantly different from Time Point 2, $_c$ significantly different from Time Point 3, $_d$ significantly different from Time Point 4

Table 12.

Analysis of change in self-reported energy between Week 1 and Week 2 (N = 39)

	Week 1		Week 2	
	M	*SD*	*M*	*SD*
Change in Self-Reported Energy*	0.17	1.55	1.44	2.14

* $p \leq .05$

Table 13.

Correlation between before school self-report fatigue at Week 1 and Week 2 (N = 39)

	Week 1 Before-School Fatigue	Week 2 Before-School Fatigue
Week 1 Before School Fatigue	-	0.49*
Week 2 Before School Fatigue		-

* $p \leq .01$

Table 14.

Correlation between before school self-reported energy at Week 1 and Week 2 (N = 39)

	Week 1 Before-School Energy	Week 2 Before-School Energy
Week 1 Before-School Energy	-	0.10
Week 2 Before-School Energy		-

* $p \leq .05$

Table 15.

Correlation between after school self-reported energy at Week 1 and Week 2 (N = 39)

	Week 1 After-School Fatigue	Week 2 After-School Fatigue
Week 1 After-School Fatigue	-	0.72*
Week 2 After-School Fatigue		-

* $p \leq .01$

Table 16.

Correlation between after school self-reported energy at Week 1 and Week 2 (N = 39)

	Week 1 After-School Energy	Week 2 After-School Energy
Week 1 After School Energy	-	0.57*
Week 2 After School Energy		-

* $p \leq .01$

Table 17.

Correlations between before-and after-school PCSS self-reported fatigue and VAS-F self-reported fatigue of Order 1 (n = 18)

	Before-School PCSS Fatigue	After-School PCSS Fatigue	Before-School VAS-F Fatigue	After-School VAS-F Fatigue
Before-School PCSS Fatigue	-	0.64*	0.41	0.11
After-School PCSS Fatigue		-	0.46	0.16
Before-School VAS-F Fatigue			-	0.36
After-School VAS-F Fatigue				-

* $p \leq .01$

Table 18.

Correlations between before-and after-school PCSS self-reported fatigue and VAS-F self-reported fatigue of Order 2 (n = 21)

	Before-School PCSS Fatigue	After-School PCSS Fatigue	Before-School VAS-F Fatigue	After-School VAS-F Fatigue
Before School PCSS Fatigue	-	0.68**	0.15	0.53*
After School PCSS Fatigue		-	.03	0.23
Before School VAS-F Fatigue			-	0.54
After School VAS-F Fatigue				-

* $p \leq .05$ ** $p \leq .01$

Table 19.

Analysis of ImPACT composite scores of athletes fatigued by school (n = 23) and athletes not fatigued by school (n = 16)

	Athletes Fatigued by School		Athletes NOT Fatigued by School	
	M	*SD*	*M*	*SD*
Verbal Memory	87.70	10.37	87.06	11.38
Visual Memory	77. 70	14.04	81.00	8.59
Processing Speed	38.76	7.05	39.92	5.94
Reaction Time	0.61	.06	0.58	.07
Total Symptoms	8.65	7.28	4.69	6.23

* $p \leq .01$

Table 20.

Analysis of PCSS baseline symptom clusters of athletes fatigued by school (n = 23) and athletes not fatigued by school (n = 16)

	Athletes Fatigued by School		Athletes NOT fatigued by school	
	M	*SD*	*M*	*SD*
Cognitive Sensory	1.65	2.35	1.13	1.75
Sleep-Arousal*	4.04	3.02	1.50	2.31
Vestibular-Somatic	1.09	2.33	0.31	0.70
Affective	1.26	2.24	1.13	2.00

*$p \leq .01$

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Appendices

Appendix A.

Recruitment Sheet: Before and After School Testing

Name: ____ Date: _______________

Please fill out the following information:

Parent name: ____

Your parent's phone number: ____

Grade: ____

Do you have transportation in order to be at school at 7 a.m.? Yes No

How many academic classes do you have per day (e.g. History, Math, Science…) (Study Hall is not a class)? ____.

a. How many AP classes do you have per day? _________________________.

b. How many Pre-AP classes do you have per day? ______________________.

c. How many elective classes do you have per day (e.g. Music, Band, Art)? ________________________________.

2. What grades to you typically make?

Above Average: A's-B's Average: C's Below Average: C's-below

3. Rate the academic difficulty of your class schedule. (1 being not difficult, 5 being extremely difficult)

1 2 3 4 5

4. How tired (cognitively) do you feel after a full day of school? (1 being not tired at all, 5 being extremely tired)

1 2 3 4 5

Please select all that apply:

Is English your second language? Yes No

Have you ever been diagnosed with Learning Disability, ADHD? Yes No

Have you been diagnosed with a concussion within the last 6 months? Yes No

Appendix B.

MORNINGNESS-EVENINGNESS QUESTIONNAIRE
Self-Assessment Version (MEQ-SA)[1]

Name: ______________________________ Date: _________________________

For each question, please select the answer that best describes you by circling the point value that best indicates how you have felt in recent weeks.

1. *Approximately* what time would you get up if you were entirely free to plan your day?

   [5] 5:00 AM–6:30 AM *(05:00–06:30 h)*
   [4] 6:30 AM–7:45 AM *(06:30–07:45 h)*
   [3] 7:45 AM–9:45 AM *(07:45–09:45 h)*
   [2] 9:45 AM–11:00 AM *(09:45–11:00 h)*
   [1] 11:00 AM–12 noon *(11:00–12:00 h)*

2. *Approximately* what time would you go to bed if you were entirely free to plan your evening?

   [5] 8:00 PM–9:00 PM *(20:00–21:00 h)*
   [4] 9:00 PM–10:15 PM *(21:00–22:15 h)*
   [3] 10:15 PM–12:30 AM *(22:15–00:30 h)*
   [2] 12:30 AM–1:45 AM *(00:30–01:45 h)*
   [1] 1:45 AM–3:00 AM *(01:45–03:00 h)*

3. If you usually have to get up at a specific time in the morning, how much do you depend on an alarm clock?

   [4] Not at all
   [3] Slightly
   [2] Somewhat
   [1] Very much

---

[1]Some stem questions and item choices have been rephrased from the original instrument (Horne and Östberg, 1976) to conform with spoken American English. Discrete item choices have been substituted for continuous graphic scales. Prepared by Terman M, Rifkin JB, Jacobs J, White TM (2001), New York State Psychiatric Institute, 1051 Riverside Drive, Unit 50, New York, NY, 10032. January 2008 version. Supported by NIH Grant MH42931. *See also:* automated version (AutoMEQ) at www.cet.org.

Horne JA and Östberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. International Journal of Chronobiology, 1976: 4, 97-100.

MORNINGNESS-EVENINGNESS QUESTIONNAIRE
Page 2

4. How easy do you find it to get up in the morning (when you are not awakened unexpectedly)?

   [1] Very difficult
   [2] Somewhat difficult
   [3] Fairly easy
   [4] Very easy

5. How alert do you feel during the first half hour after you wake up in the morning?

   [1] Not at all alert
   [2] Slightly alert
   [3] Fairly alert
   [4] Very alert

6. How hungry do you feel during the first half hour after you wake up?

   [1] Not at all hungry
   [2] Slightly hungry
   [3] Fairly hungry
   [4] Very hungry

7. During the first half hour after you wake up in the morning, how do you feel?

   [1] Very tired
   [2] Fairly tired
   [3] Fairly refreshed
   [4] Very refreshed

8. If you had no commitments the next day, what time would you go to bed compared to your usual bedtime?

   [4] Seldom or never later
   [3] Less that 1 hour later
   [2] 1-2 hours later
   [1] More than 2 hours later

MORNINGNESS-EVENINGNESS QUESTIONNAIRE
Page 3

9. You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week, and the best time for him is between 7-8 AM *(07-08 h)*. Bearing in mind nothing but your own internal "clock," how do you think you would perform?

   [4] Would be in good form
   [3] Would be in reasonable form
   [2] Would find it difficult
   [1] Would find it very difficult

10. At *approximately* what time in the evening do you feel tired, and, as a result, in need of sleep?

   [5] 8:00 PM–9:00 PM *(20:00–21:00 h)*
   [4] 9:00 PM–10:15 PM *(21:00–22:15 h)*
   [3] 10:15 PM–12:45 AM *(22:15–00:45 h)*
   [2] 12:45 AM–2:00 AM *(00:45–02:00 h)*
   [1] 2:00 AM–3:00 AM *(02:00–03:00 h)*

11. You want to be at your peak performance for a test that you know is going to be mentally exhausting and will last two hours. You are entirely free to plan your day. Considering only your "internal clock," which one of the four testing times would you choose?

   [6] 8 AM–10 AM *(08–10 h)*
   [4] 11 AM–1 PM *(11–13 h)*
   [2] 3 PM–5 PM *(15–17 h)*
   [0] 7 PM–9 PM *(19–21 h)*

12. If you got into bed at 11 PM *(23 h)*, how tired would you be?

   [0] Not at all tired
   [2] A little tired
   [3] Fairly tired
   [5] Very tired

MORNINGNESS-EVENINGNESS QUESTIONNAIRE
Page 4

13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which one of the following are you most likely to do?

[4] Will wake up at usual time, but will not fall back asleep
[3] Will wake up at usual time and will doze thereafter
[2] Will wake up at usual time, but will fall asleep again
[1] Will not wake up until later than usual

14. One night you have to remain awake between 4-6 AM *(04-06 h)* in order to carry out a night watch. You have no time commitments the next day. Which one of the alternatives would suit you best?

[1] Would not go to bed until the watch is over
[2] Would take a nap before and sleep after
[3] Would take a good sleep before and nap after
[4] Would sleep only before the watch

15. You have two hours of hard physical work. You are entirely free to plan your day. Considering only your internal "clock," which of the following times would you choose?

[4] 8 AM–10 AM *(08–10 h)*
[3] 11 AM–1 PM *(11–13 h)*
[2] 3 PM–5 PM *(15–17 h)*
[1] 7 PM–9 PM *(19–21 h)*

16. You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week. The best time for her is between 10-11 PM *(22-23 h)*. Bearing in mind only your internal "clock," how well do you think you would perform?

[1] Would be in good form
[2] Would be in reasonable form
[3] Would find it difficult
[4] Would find it very difficult

MORNINGNESS-EVENINGNESS QUESTIONNAIRE
Page 5

17. Suppose you can choose your own work hours. Assume that you work a five-hour day (including breaks), your job is interesting, and you are paid based on your performance. At *approximately* what time would you choose to begin?

[5] 5 hours starting between 4–8 AM *(05–08 h)*
[4] 5 hours starting between 8–9 AM *(08–09 h)*
[3] 5 hours starting between 9 AM–2 PM *(09–14 h)*
[2] 5 hours starting between 2–5 PM *(14–17 h)*
[1] 5 hours starting between 5 PM–4 AM *(17–04 h)*

18. At *approximately* what time of day do you usually feel your best?

[5] 5–8 AM *(05–08 h)*
[4] 8–10 AM *(08–10 h)*
[3] 10 AM–5 PM *(10–17 h)*
[2] 5–10 PM *(17–22 h)*
[1] 10 PM–5 AM *(22–05 h)*

19. One hears about "morning types" and "evening types." Which one of these types do you consider yourself to be?

[6] Definitely a morning type
[4] Rather more a morning type than an evening type
[2] Rather more an evening type than a morning type
[1] Definitely an evening type

_____ Total points for all 19 questions

Appendix C.

Visual Analogue Scale to Evaluate Fatigue Severity (VAS-F)

ID #_________ Date__________

Time _________a.m. __________p.m.

We are trying to find out about your level of energy before and after your night of sleep. There are 18 items we would like you to respond to. This should take less than 1 minute of your time. Thank you.

DIRECTIONS: You are asked to circle a number on each of the following lines to indicate how you are feeling RIGHT NOW.

For example, suppose you have not eaten since yesterday. What number would you circle below?

not at all hungry 0 1 2 3 4 5 6 7 8 9 10 extremely hungry

You would probably circle a number closer to the "extremely hungry" end of the line. This is where I put it:

not at all hungry 0 1 2 3 4 5 6 (8) 9 10 extremely hungry

NOW PLEASE COMPLETE THE FOLLOWING ITEMS:

1. not at all **tired** 0 1 2 3 4 5 6 7 8 9 10 extremely **tired**
2. not at all **sleepy** 0 1 2 3 4 5 6 7 8 9 10 extremely **sleepy**
3. not at all **drowsy** 0 1 2 3 4 5 6 7 8 9 10 extremely **drowsy**
4. not at all **fatigued** 0 1 2 3 4 5 6 7 8 9 10 extremely **fatigued**
5. not at all **worn out** 0 1 2 3 4 5 6 7 8 9 10 extremely **worn out**
6. not at all **energetic** 0 1 2 3 4 5 6 7 8 9 10 extremely **energetic**
7. not at all **active** 0 1 2 3 4 5 6 7 8 9 10 extremely **active**
8. not at all **vigorous** 0 1 2 3 4 5 6 7 8 9 10 extremely **vigorous**

9.	not at all **efficient**	0	1	2	3	4	5	6	7	8	9	10	extremely **efficient**
10.	not at all **lively**	0	1	2	3	4	5	6	7	8	9	10	extremely **lively**
11.	not at all **bushed**	0	1	2	3	4	5	6	7	8	9	10	totally **bushed**
12.	not at all **exhausted**	0	1	2	3	4	5	6	7	8	9	10	totally **exhausted**
13.	**keeping my eyes open** is no effort at all	0	1	2	3	4	5	6	7	8	9	10	**keeping my eyes open** is a tremendous chore
14.	**moving my body** is no effort at all	0	1	2	3	4	5	6	7	8	9	10	**moving my body** is a tremendous chore
15.	**concentrating** is no effort at all	0	1	2	3	4	5	6	7	8	9	10	**concentrating** is a tremendous chore
16.	**carrying on a conversation** is no effort at all	0	1	2	3	4	5	6	7	8	9	10	**carrying on a conversation** is a tremendous chore
17.	I have absolutely **no desire to close my eyes**	0	1	2	3	4	5	6	7	8	9	10	I have a tremendous **desire to close my eyes**
18.	I have absolutely **no desire to lie down**	0	1	2	3	4	5	6	7	8	9	10	I have a tremendous **desire to lie down**

Appendix D.

PSQI_PW

ID ___ ___ ___ ___ ___ ___   Date ___ ___ / ___ ___ / ___ ___   Time ________ AM / PM
m m d d y y

INSTRUCTIONS:
The following questions relate to your usual sleep habits during the past week only. Your answers should indicate the most accurate reply for the majority of days and nights in the past week. Please answer all questions.

1. During the past week, what time have you usually gone to bed at night?

   BED TIME __________

2. During the past week, how long (in minutes) has it usually taken you to fall asleep each night?

   NUMBER OF MINUTES __________

3. During the past week, what time have you usually gotten up in the morning?

   GETTING UP TIME __________

4. During the past week, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

   HOURS OF SLEEP PER NIGHT __________

For each of the remaining questions, check the one best response. Please answer all questions.

5. During the past week, how often have you had trouble sleeping because you . . .

   a) Cannot get to sleep within 30 minutes

   Not during the past week _____   One day in the past week _____   Two days in the past week _____   Three or more days in the past week _____

   b) Wake up in the middle of the night or early morning

   Not during the past week _____   One day in the past week _____   Two days in the past week _____   Three or more days in the past week _____

   c) Have to get up to use the bathroom

   Not during the past week _____   One day in the past week _____   Two days in the past week _____   Three or more days in the past week _____

   d) Cannot breathe comfortably

   Not during the past week _____   One day in the past week _____   Two days in the past week _____   Three or more days in the past week _____

PSQI_PW

ID ___ ___ ___ ___ ___ ___

Date ___ ___ / ___ ___ / ___ ___
m m d d y y

e) Cough or snore loudly

Not during the past week _____ One day in the past week _____ Two days in the past week _____ Three or more days in the past week _____

f) Feel too cold

Not during the past week _____ One day in the past week _____ Two days in the past week _____ Three or more days in the past week _____

g) Feel too hot

Not during the past week _____ One day in the past week _____ Two days in the past week _____ Three or more days in the past week _____

h) Had bad dreams

Not during the past week _____ One day in the past week _____ Two days in the past week _____ Three or more days in the past week _____

i) Have pain

Not during the past week _____ One day in the past week _____ Two days in the past week _____ Three or more days in the past week _____

j) Other reason(s), please describe ____

____

How often during the past week have you had trouble sleeping because of this?

Not during the past week _____ One day in the past week _____ Two days in the past week _____ Three or more days in the past week _____

6. During the past week, how would you rate your sleep quality overall?

Very good ____________

Fairly good ____________

Fairly bad ____________

Very bad ____________

PSQI_PW

ID ___ ___ ___ ___ ___ ___

Date ___ ___ / ___ ___ / ___ ___
m m d d y y

7. During the past week, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

   Not during the past week _____ One day in the past week _____ Two days in the past week _____ Three or more days in the past week _____

8. During the past week, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

   Not during the past week _____ One day in the past week _____ Two days in the past week _____ Three or more days in the past week _____

9. During the past week, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

   No problem at all ____________

   Only a very slight problem ____________

   Somewhat of a problem ____________

   A very big problem ____________

10. Do you have a bed partner or room mate?

   No bed partner or room mate ____________

   Partner/room mate in other room ____________

   Partner in same room, but not same bed ____________

   Partner in same bed ____________

Appendix E.

Food Intake Survey

Name: ____________________________ **Date: ______________**

5. **Did you eat breakfast today? Yes No**
   IF YES -
   a. **About what time did you eat breakfast (e.g., 6:30 am)? ____________________**
   b. **Please describe what you ate for breakfast (e.g., 1 bowl of cereal with milk).**
   ____
   ____
   ____

6. **Did you eat lunch today? Yes No**
   IF YES -
   a. **About what time did you eat lunch (e.g., 12:30 pm)? ______________________**
   b. **Please describe what you ate for lunch (e.g., hamburger with fries and a bottle of water).**
   ____
   ____
   ____

7. **Did you drink any caffeine today (e.g., coffee, soda, energy drinks…)? Yes No**
   IF YES -

Exactly what did you drink (e.g., coffee, energy drinks, soda…)?	When did you drink it (e.g., 6:30 am)?	Approximately how much did you drink?

8. **Do you take any supplements? Yes No**
   a. **About what time did you take the supplements (e.g., 6:30 am, 12:30 pm)?**
   ____
   b. **Exactly what supplement did you take (e.g., creatine, protein, pre-workout drinks, amino acids)?**
   ____

Appendix F.

Name: ____________________________ **Date:** ______________

Effort Form

AFTER YOU COMPLETE IMPACT

Please CIRCLE your effort (i.e., how hard did you try) while taking this test:

No Effort (I did not try at all)	**Low Average Effort** (I tried a little bit)	**Average Effort** (I tried, but could have tried harder)	**High Effort** (I gave my best effort)
1	**2**	**3**	**4**

Appendix G.

Cognitive Demand of School Intake Form

Name: ___________________________ **Date: _____________**

1. **How many academic classes do you have per day (e.g. History, Math, Science…) (Study Hall is not a class)? ____.**
   a. **How many AP classes do you have per day? ____________________.**
   b. **How many Pre-AP classes do you have per day? _____________.**
   c. **How many elective classes do you have per day (e.g. Music, Band, Art)? ______________**

2. **Generally speaking, what kind of student are you?**

Above Average: A's-B's **Average: C's** **Below Average: C's-below**

3. **Rate the academic difficulty of your class schedule. (1 being not difficult, 5 being extremely difficult) _____________________.**

Appendix H.

UNIVERSITY OF ARKANSAS

Office of Research Compliance
Institutional Review Board

February 27, 2017

MEMORANDUM

TO:	R.J. Elbin Caitlin Gallions Laura Zaring Afton Baird Nate D'Amico Natalie Sherwood	Morgan Anderson Evan Dobbs Liza Epley Melissa Anderson Sam Mohler
FROM:	Ro Windwalker IRB Coordinator	
RE:	PROJECT MODIFICATION	
IRB Protocol #:	14-10-159	
Protocol Title:	*Comparing Before- and After-School Neurocognitive Performance in High School Athletes: Implications for Concussion Management*	
Review Type:	☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB	
Approved Project Period:	Start Date: 02/27/2017 Expiration Date: 10/16/2017	

Your request to modify the referenced protocol has been approved by the IRB. **This protocol is currently approved for 80 total participants.** If you wish to make any further modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

Please note that this approval does not extend the Approved Project Period. Should you wish to extend your project beyond the current expiration date, you must submit a request for continuation using the UAF IRB form "Continuing Review for IRB Approved Projects." The request should be sent to the IRB Coordinator, 109 MLKG Building.

For protocols requiring FULL IRB review, please submit your request at least one month prior to the current expiration date. (High-risk protocols may require even more time for approval.) For protocols requiring an EXPEDITED or EXEMPT review, submit your request at least two weeks prior to the current expiration date. Failure to obtain approval for a continuation *on or prior to* the currently approved expiration date will result in termination of the protocol and you will be required to submit a new protocol to the IRB before continuing the project. Data collected past the protocol expiration date may need to be eliminated from the dataset should you wish to publish. Only data collected under a currently approved protocol can be certified by the IRB for any purpose.

If you have questions or need any assistance from the IRB, please contact me at 109 MLKG Building, 5-2208, or irb@uark.edu.

109 MLKG • 1 University of Arkansas • Fayetteville, AR 72701-1201 • (479) 575-2208 • Fax (479) 575-6527 • Email irb@uark.edu

Appendix I.

Before-And-After School Study Script

Good morning/Good afternoon, my name is____________________. I am here from the University of Arkansas, specifically the Office of Sport Concussion Research. Today you will be completing a 20-minute computer test that will measure your memory and reaction time. It is very important that you try your best on this test as we want to know how you do on this test before and after school.

Before we get started please turn off and put away any electronic devices. This morning/afternoon you will be completing the NFL concussion assessment called ImPACT. ImPACT will take approximately 25 minutes if there are no disruptions and everyone is quiet. We will all start and end together as a group.

The first part of the test will ask you questions about your health and concussion history. Please begin now and follow the instructions. Once you have completed the background information a screen will prompt you to start the test. Please DO NOT click continue until I say so. We want to make sure there are no more questions or distractions before everyone starts the test. If you have any questions please raise your hand.

The next part of the test will ask you questions about your current symptoms. Remember to answer the questions as to how you are feeling right now. Please begin now and follow the instructions. Once you have completed the background information a screen will prompt you to start the test. Please DO NOT click continue until I say so. We want to make sure there are no more questions or distractions before everyone starts the test. If you have any questions please raise your hand.

Before you begin the actual cognitive tasks I want to talk about how you can earn a 40 dollar cash prize. If you give maximum effort on both of your testing sessions, you will earn a 40.00 cash prize. If you give less than maximum effort, you will earn less than the 40.00 prize. Your effort will be measured by your overall scores on both your testing sessions. You will not be paid until your last visit is complete.

After you complete ImPACT, there are 5 short questionnaires located under your keyboard. Please answer these questionnaires to the best of your ability. Please read and follow the directions carefully and raise your hand if you have any questions.

Please DO NOT TALK to one another. You may begin the test.