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Determining the Appropriate Timing of Administration for Baseline Computerized Neurocognitive Testing (CNT) Following Maximal Exertion

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Abstract

Background: Computerized neurocognitive testing is part of the recommended multi-faceted approach to SRC assessment. Prior research has suggested that maximal exertion negatively effects CNT test scores. **Purpose:** To identify the appropriate timing of the administration of CNT following maximal exertion in healthy college-aged student athletes. **Study Design:** Prospective, random cross-over, repeated measures design. **Methods:** Week one participants fill out intake forms and then complete a baseline ImPACT test. The following three weeks, individuals were administered a VO2 max cycle ergometer test. Following the test participants will rest for <5 (immediate), 15, or 30 minutes before re-taking ImPACT. **Results:** Immediately following maximal exertion, negative composite scores, relative to baseline, were seen in 1/6 for verbal memory, 2/6 for visual memory, 2/6 participants for visual motor, and 2/6 participants for reaction time. Post-test 15 minutes decrements were seen for 0/6 participants for verbal memory, 2/6 participants for visual memory, 1/6 participants for visual motor, and 2/6 participants for reaction time. Post-test 30 minutes decrements were seen for 1/6 participants for verbal memory, 1/6 participants for visual memory, 1/6 participants for visual memory, and 3/6 participants for reaction time. **Discussion:** Time constraints, schedule conflicts, and participant availability was a major barrier to recruitment efforts. A small pilot study was conducted. Results from this pilot were not consistent with previous research. Mode of exercise, randomization of baseline trials, and better participant compliance should be addressed before moving forward.

Introduction

Approximately 1.6-3.8 million sport and recreation-related concussions occur each year in the United States (Langlois, Rutland-Brown, & Wald, 2006). Sport-related concussion (SRC) can negatively affect the physical, emotional, social, and cognitive functioning of athletes. If clinically mismanaged, the consequences of SRC on long-term health can be catastrophic- resulting in chronic post-concussion symptoms, permanent brain damage, and although very rare, result in death in younger athlete populations. Therefore, to ensure that athletes with concussions receive proper care and avoid poor recovery outcomes, a multi-faceted, objective assessment approach for SRC management is recommended (McCrory, et al., 2013).

Approximately 63% of all sport-related concussions go unreported (McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004). Traditionally, sports medicine professionals primarily relied on self-reported symptoms to assess and manage concussion. However, many athletes fail to disclose or minimize their symptoms because of eagerness to return to play, lack of knowledge, or fear of letting their teammates down (McCrea et al., 2004). Due to the subjectivity and lack of accuracy associated with self-reported symptoms, objective testing is needed. These tests, used in conjunction with self-reported symptoms, better quantify impairment and provide a visual representation of recovery following a concussion. One test currently used for assessment of sport-related concussion is computerized neurocognitive testing (CNT), which objectively measures several aspects of cognitive functioning (Van Kampen, Lovell, Pardini, Collins & Fu, 2006).

Computerized neurocognitive testing is part of the recommended multi-faceted approach to SRC assessment. This assessment includes a battery of cognitive tasks measuring verbal memory, visual design memory, concentration, visual processing, and reaction time (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009). Somewhat similar to the "old fashioned" paper and pencil neurocognitive tests, the improvements in technology allow this type of test to be governed by a computer which afford the ability to administer multiple versions, automated scoring, and standardized administration. This assessment is administered both before and after suspected concussion, and has been called the "cornerstone" of current SRC assessment and management (Broglio, et al., 2014). Pre-injury (baseline) and post-injury CNT scores can be compared and analyzed by sports medicine professionals to better evaluate cognitive function and recovery. CNT can also provide a visual depiction of an individual's condition helping to bridge the gap between the athlete, coaches, parents, academic personnel and the clinician (Broglio, et al., 2014). Ensuring the accuracy of the baseline CNT assessment is critical to SRC management.

The accuracy of baseline CNT is a key component of SRC management (Collins, Kontos, Reynolds, Murawski, & Fu, 2014). Baseline CNT administration is a “snapshot” of cognitive performance. It is imperative sports medicine professionals conduct baseline testing in an environment and at a time that will enable athletes to put forth their best effort, and perform at their maximum potential. Researchers have identified several factors that negatively influence CNT baseline scores including learning disabilities, attention deficit hyperactivity disorder, (Elbin, Kontos, Kegel, Johnson, Burkhart, & Schatz, 2013), concussion history (Broglio, et al., 2014), testing environment (Moser, Schatz, Neidzwski, & Ott, 2011), and exertion (Covassin, Weiss, Powell, & Womack, 2007). Sports medicine professionals should attempt to control these factors to achieve optimal baseline performance for their athletes.

One factor influencing the accuracy of the baseline CNT assessment is exertion. Several studies report a negative relationship between the effects of maximal exercise and cognitive performance (Covassin, et al., 2007; Dietrich 2006; Nada, Balde, & Manjunatha 2013). These projects analyzed cognition after a bout of maximal (Covassin, et al., 2007), high-intensity (Nada, Balde, & Manjunatha) and locally fatigued state muscles (Dietrich 2006). All three studies detected a negative change in cognitive function when compared to baseline or controls. In contrast, other studies have found moderate physical activity to actually stimulate cognitive performance (Hillman, Snook, and Jerome, 2003; Pontifex, Hillman, Fernhall, and Thompson, 2009; Brisswalter, Collardeau, & Rene, 2002). Other studies examining the effects of maximal exertion on cognitive performance have produced mixed findings (Coles & Tomporowski, 2008). This inconsistency is most likely due to differing methodologies, exertion protocols, and outcome measures used when assessing cognition.

Covassin and colleagues (2007) reported that maximal exercise has negative effects on CNT baseline scores when compared to the non-exerted controls. Covassin (2007) administered CNT immediately following the completion of a maximal exertion protocol. When compared to a non-exerted control group, the experimental group performed significantly lower on the post-exertion CNT. The experimental group also showed significantly lower verbal memory composite scores when compared to their own baseline. The results of Covassin's study implies that CNT should not be administered directly after exertion. Although research suggests maximal exercise negatively affects the outcome on CNT, the optimal recovery time following a bout of maximal exertion has not been examined.

This research is significant as anecdotal reports from sports medicine professionals suggest baseline testing is often administered in the short time following a bout of physical activity (e.g., strength and conditioning workout) due to time constraints of a rigorous sport environment. Pre-season baseline testing is often an afterthought for many coaches during the start of the new season, and is squeezed into a demanding schedule. Despite this potentially flawed method, no study has examined how long the sports medicine professional should wait before administering baseline CNT following maximal exertion.

If maximal exertion negatively impacts baseline scores, concussions may go undetected or mismanaged. Previous research suggests that immediately administering a CNT baseline following maximal exertion results in decreased scores (Covassin, et al., 2007), potentially confounding post-SRC management and return to play decisions. The wait-time for administering CNT following a bout of maximal exertion is unknown and there is currently no recommended time interval to wait before testing. In order to outline "best practice" guidelines for baseline CNT administration, additional research concerning maximal exercise exertion and recovery is needed. This data will directly impact CNT baseline-testing practices of sports medicine professionals. **The purpose of this study is to identify the appropriate timing of the administration of CNT following maximal exertion in healthy college-aged student athletes.**

Literature Review

Concussion 101

It is estimated in the United States 1.6 to 3.8 million sport related concussions occur each year (Langlois, et al., 2006). Studies show that the risk of concussion is present in almost every sport, with the highest prevalence in contact sports. Among American high school and collegiate athletes, football accounts for 40.2% of reported concussions followed by girls soccer (21.5%), boys soccer (15.4%), and girls basketball (9.5%); higher percentages are also found in both youth and female populations (Gessel, Fields, Collins, Dick, & Comstock 2007). Left undetected or mismanaged a concussion can cause potentially serious long-term effects and consequences.

Definition

Concussion is defined as a complex injury resulting from a cascade of neurometabolic events following biomechanical trauma, resulting in variable symptoms and impairments (Halstead & Walter, 2010). Clinical, pathological and biomechanical paradigms utilized to help define this injury, according to the 4th International Conference on Concussion in 2012, include: transmission of direct or indirect force transmission to the head, onset of short-lived neurological impairments due to functional disturbances rather that structural injury, and symptoms that normally resolve with adequate rehabilitation (McCrory, et al., 2013).Concussions have also been defined as a mild traumatic brain injury (mTBI). Some researchers believe that this nomenclature is misleading; as not all mTBI are concussions- rather, concussions are a distinct, less severe subclass of mTBIs (Harmon, et al., 2013).

Biomechanics

A concussion occurs as a result of the collision of the brain with the skull. The human brain is suspended in cerebral spinal fluid. Head impacts occurring either directly to the head or elsewhere to the body resulting in whiplash causes propulsion of the brain within the skull. The mechanical components of a concussion is a result of linear and or rotational forces. Linear impact occurs when the head is struck while stationary or strikes a stationary object causing acceleration/deceleration of the skull and subsequent brain movement (Broglio, et al., 2010). Rotational impacts occur when the head rotates in response to an angular blow to the head. The human brain is suspended in cerebral spinal fluid. Head impacts occurring either directly to the head or elsewhere to the body resulting in whiplash causes propulsion of the brain within the skull.

Pathophysiology

The underlying pathophysiology of concussion is comprised of a cascade of neurometabolic events. Defects within brain tissue cannot be seen on a macroscopic level, as the damage occurs near the ends of individual neurons. Head impact forces cause neurons to become stretched or stressed. This stress induces a cascade of events. Cerebral blood flow is reduced and neurotransmitters are readily released (Barkhoudarian, Hovda, & Giza, 2011). The neurotransmitters cause an efflux of K+ and an influx of Na+ disturbing the ionic balance (Barkhoudarian, et al., 2011). Once homeostasis is disrupted sodium and potassium pumps use glucose reserves to restore original ionic balance in the brain (Barkhoudarian, et al., 2011). Moreover, mitochondrial activity is reduced as magnesium levels are also affected. Decreased mitochondrial levels further the energy crisis as magnesium functions to regulate mitochondrial membrane potential and ATP production (Collins, Iverson, Gatez, Meehan, & Lovell, 2011). Hyperglycolysis and reduced blood flow, combined with decreased mitochondrial oxidative capacity increases anaerobic metabolism reliance. Eventually a metabolic mismatch occurs as the body is unable to supply the brain with sufficient energy. This mismatch paired with, lactic acid accumulation, decreased magnesium levels, free radical production, and inflammatory response is believed to cause the outward symptoms that we identify as a concussion. These markers have been studied in both animal and human subjects and are thought to have cumulative effect in repeat injuries (Giza & Hovda, 2001).

Signs and Symptoms

A concussion is a heterogeneous injury that can present itself differently in each case. The diagnosis of concussions is centered on a range of signs and symptoms. For years, loss of consciousness (LOC) was used to identify and diagnose concussion. Early LOC, amnesia, and other cognitive impairments may be a result of a "spreading depression" like state (Giza & Hovda, 2001). Although LOC is a major red flag, it is important to note that it is not a symptom used to determine the existence of a concussion (Ommaya & Gennarelli, 1974; Lovell, Iverson, Collins, McKeag, & Maroon, 1999). In fact, many studies report that less than 14% of individuals with a concussion will lose consciousness (Lau, Kontos, Collins, Mucha, & Lovell, 2011; Guskiewicz, Weaver, Padua, & Garrett, 2000; McCrea, et al., 2003). Other symptoms of concussion include: headache, nausea, vomiting, vestibular disturbances, dizziness, fatigue, sleep pattern disturbances, drowsiness, sensitivity to light and or noise, irritability, sadness, emotional, numbness or tingling, feeling slowed or foggy, difficulty concentrating, difficulty remembering, and visual problems (Collins, et al., 2014; Meehan III, et al., 2010). Headache and dizziness are the most commonly reported symptoms (Guskiewicz, et al., 2000; Collins, et al., 2011). In most cases these symptoms will resolve within a week of the injury but in some cases these symptoms can linger for multiple weeks, or months.

Traditionally clinicians grouped symptoms into four distinct categories: cognitive-fatigue, emotional (affective), physical (somatic), and sleep (Kontos, et al., 2012). Recent research suggests that symptoms occurring within the first seven days should be divided into primary and secondary symptoms (Collins, et al., 2014). This type of grouping suggests that patients should be treated similar in the first seven days (Collins, et al., 2014). If symptoms persist beyond seven days clinical trajectories are then used to properly assess, track and treat the patient. Six clinical trajectories have been identified: vestibular, ocular-motor, cognitive, post-traumatic migraine, cervical, anxiety/mood (Collins, et al., 2014). When interpreting and assessing symptom reports, clinicians should consider both age and sex of the individual. Research shows that male and female athletes commonly experience different symptom trajectories and younger individuals perform poorer in comparison to older test subjects (Covassin, Elbin, Harris, Parker, & Kontos, 2012). Research studying both high school and college athletes suggests that gender may also play a role in symptom presentation. Males experienced more cognitive related symptoms while females reported more neurobehavioral symptoms (Wasserman, Kerr, Zuckerman, & Covassin, 2015).

Some research has looked for correlation between on field concussion presentation and recovery track. Chronic and sub-acute symptoms can cause student athletes to perform poorly in school, become socially withdrawn, and become depressed. The psychological aspects play major roles in rehabilitation (Wiese-Bjornstal, White, Russel, & Smith, 2015).

Nevertheless, preventing and treating long-lasting effects of concussion is the focus of many clinicians. These effects are more likely to occur if the individual returns to play without properly recovering from their concussion. Although the evidence supporting second impact syndrome (SIS) is inconclusive, it is clear that the brain is more vulnerable to injury when still in a stage of metabolic dysfunction. Second impact syndrome is a rare catastrophic brain injury that results in edema and a breakdown of the blood-brain barrier, following multiple concussive injuries (Collins, et al., 2011). This syndrome occurs when individual receives another concussive blow before fully recovering from the first concussion. Many researchers believe that the brain is more susceptible to concussion, when in the hypermetabolic stage (Laurer et al., 2001). For this reason it is important to accurately detect, and monitor concussions to prevent further damage.

Management Approaches for Sport-Related Concussion

A multidisciplinary approach is recommended in order to best account for the variety of presentations (McCrory, et al., 2013; Johnson, Kegel, & Collins, 2011). One facet of current concussion assessment is The Post-Concussion Symptom Scale (PCSS), based on self-reported symptoms. Twenty-two symptoms are scored on a 7-point Likert scale (0-6), these symptoms can be grouped into specific categories. In more recent literature some focus has been given to identifying and focusing treatment based on specific symptom categories such as vestibular, cognitive, and psychological pathways (Collins, et al., 2014). This method helps professionals more specifically diagnose and treat the individual. In addition to trajectory treatment pathways, clinicians follow a standardized return to play exertion protocol.

Return-to-play (RTP) protocol is used to help integrate athletes safely back into his or her sport. Rest was once believed to be the best mechanism of treatment for concussed individuals but, research shows that a slow progression both back into normal everyday encounters and physical activity is beneficial. The current RTP protocol endorsed and used by many athletic trainers and clinicians use a five step progression. Return-to-play decisions should be individualized, and progression can vary greatly between athletes (Harmon, et al., 2013). It is important to note that over 27% of athletes who reported being symptom free after RTP exertion did not pass all of the neurocognitive tests (McGrath, et al., 2013). This is yet another reason why CNT is an important tool used in concussion recovery.

Computerized Neurocognitive Testing

Neurocognitive testing has been increasingly useful in assessing concussion for the past 30 years, and is now considered a cornerstone in concussion management. Although the roots of cognitive testing lie in traumatic brain injury research, much of the USA's sport-related concussion testing can be attributed to J. T. Barth. In 1976 Barth began by using tests shown to detect deficits caused by mild head trauma, and complied a relatively brief test battery. This test consisted of nine different cognitive function tests and took approximately 45 minutes to administer. Barth and colleagues (Barth, et al., 1983) collected "baseline" data from over 2,300 football players around the nation. In the event of a concussion the same battery was administered after 24 hours, five days, and ten days post-concussion. This study found significant differences between baseline and concussed players 24 hours and five days after a concussion. This study helped create a foundation for the use of neurocognitive and neuropsychological testing in the diagnosis of concussion.

With the advancement in technology researchers developed computerized neurocognitive tests. These tests are an essential component of current concussion management (McCrory, et al., 2013). CNT are more sensitive to fractional reflex delays and also provided a more economical and useful testing method as compared to the paper and pencil tests. CNT has been validated by numerous researchers as a reliable measure of cognitive function (Van Kampen, et al., 2006). Specifically the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) tool has been validated by several research studies and measure seven different features cognitive health. ImPACT collects information concerning demographics, concussion history symptoms, and assesses verbal memory, visual memory, processing speed, reaction time, and impulse control (Lovell, 2006).

Computerized Neurocognitive testing is best administered in a prospective and retrospective method. Prospective baseline tests are administered before an athlete begins contact activities and gives a snapshot of an individual's cognitive function. After a suspected concussion the battery is repeated and the results are compared. Cognitive impairment, slower reaction times, and lower composite scores calculated by the CNT are indications of a concussion.

Factors Effecting Computerized Neurocognitive Testing

There are several factors that affect computerized neurocognitive testing. First, the athlete's motivation has been shown to affect the outcome of the test (Bailey & Arnett, 2006). ImPACT has an internal validity indicator that helps to red-flag scores that may be a result of an athlete "sandbagging" the test. Even with the validity measure it is difficult to assess the individual’s motivation and effort. Other factors such as sex (Covassin, et al., 2012), age (Covassin, et al., 2012) learning disabilities (Elbin et al., 2013), sleep quality (Mihalik et al., 2013), and concussion history (Broglio et al., 2014) can skew the CNT results. Another factor that can negatively affect the results of CNT is exertion. Both cognitive fatigue and physiological fatigue is shown to have significant effects on cognition. Despite several factors that have shown to affect the accuracy of CNT these test are useful in objectively assessing the cognitive effects of a concussion. Research shows that when computerized neuropsychological testing is used, in evaluation of HS athletes, individuals are less likely to return to play on the same day (Meehan III, et al., 2010). Clearly CNT is a beneficial tool for concussion diagnosis

Exertion effects on Cognition

In 1976, Wrisberg and Herbert found that physical fatigue is a performance variable and that different fatigue mechanisms could result from different types of exercise (Wrisberg & Herbert, 1976). Much of the research concerning cognition and exercise is centered on moderate intensity exercise as a mechanism to enhance or "arouse" (Nada et al., 2013). Other studies have shown that physical activity, when completed to exhaustion, results in negative cognitive effects (McMorris & Hale, 2012). Although all of these studies have important implications, the negative effects of exertion found in literature has a more important hold on concussion neurocognitive testing. High intensity and maximal exercise has been shown to negatively impact neurocognitive function (Covassin, et al., 2007; Whyte, Gibbons, Kerr, & Moran, 2014). In Covassin's study baseline CNT was administered to all participants. The treatment group completed a VO_2 max treadmill test and then immediately took ImPACT a second time. The control group remained at rest for 15 min (the approximate time it takes for completion of a VO2 max treadmill test) an also took ImPACT a second time. Means and standard deviations were calculated and the level of significance was set ($p=0.05$). Significant decreases were seen in verbal memory, specifically immediate recall, and delayed recall. Separating neurocognitive deficits caused by concussion or exhaustion are nearly impossible to tease apart. The results of this study imply that CNT should not be administered immediately after maximal exertion. Exertion has effects on cognition and these detriments could negatively impact the validity of CNT based concussion diagnosis.

Transient Hypofrontality Theory

One theory that researchers have proposed to explain the negative effects of exertion on cognition is the transient hypofrontality theory. The hypofrontality theory argues that higher levels of cognitive function are impaired as a result of exercise (Dietrich, 2006). The brain receives a constant supply of nutrients and oxygen despite an increase in cardiac output due to exercise (Ide & Secher, 2000). During exercise, blood carrying oxygen and nutrients is directed towards the working muscles as a smaller percentage of blood is allocated for the brain (Ide & Secher, 2000). Exercise and movement of large muscle groups requires a significant amount of neural stimulation. This increase in stimulation results in depressed prefrontal cortex functioning, therefore a decrease in higher level cortical functioning. During exercise utilities needed for higher-level executive control are depressed. The transient hypofrontality hypothesis suggests that higher-level cognitive processing requiring prefrontal cortex activation are temporarily impaired during and immediately after exercise (Dietrich, 2006). This theory has been further supported by several other studies showing that exercise impairs executive functioning and response inhibition. A study by Del Giorno and colleagues (2010) also proposed that hypofrontality theory might also be responsible for decreases in performance after exercise is terminated. They found that executive control measures remained impaired for a significant amount of time post exercise, potentially until the brain has time to return to homeostasis (Del Giorno, Hall, O'Leary, Bixby, & Miller, 2010).

This theory supports the idea that exercise causing significant exertion can potentially depress cortical functioning. Higher level cortical functioning is responsible for several aspects of cognition, including those measured by CNT. This theory helps potentially explain why baseline scores are depressed after maximal exertion. According to this theory the appropriate timeline for administering CNT after maximal exertion depends on the amount of time it takes the brain to return to normal function and homeostasis.

VO2 Maximal Testing as a Measure of Exhaustion

According to anecdotal reports baseline testing is often worked in and around games, practices, and conditioning, potentially leaving student athletes in a exerted state. Maximal exertion can be measured several different ways including using a cycle ergometer. A maximal VO_2 test is terminated when or if heart rate fails to increase with increasing intensity, VO_2 plateau with increasing workload, respiratory exchange ratio greater than or equal to 1.1, or a rating of perceived exertion greater than 18 on a 6-20 scale. (ASCM's Guidelines for Exercise Testing and Prescription, 2014)

Methods

Research Design: This study will use a prospective, repeated measures design

Hypothesis: Significant composite score decrements will be seen in immediate and post-15 trials when compared to baseline composite scores, while post-30 data will be comparable to baseline scores.

Participants: A total of six intramural or club sport athletes will be recruited for study. To be included in this study all participants must be a current intramural or club sport athlete and be healthy enough to complete a maximal oxygen consumption (VO_2max) assessment. Any participant with diagnosed learning disability, ADHD, psychological disorder (e.g., clinical depression/anxiety), history of substance abuse, are non-English speaking, or reported sustaining a concussion within the last six months of participation will be excluded from the study.

Instrumentation/Measures

Neurocognitive performance: Neurocognitive performance will be measured using The Immediate Post Concussion Assessment and Cognitive Testing (ImPACT) which is one type of CNT. The ImPACT battery takes approximately 20-25 minutes to complete, has five different test versions to minimize practice effects, and produces outcome 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 8 days across 4 administrations, yielding correlation coefficients ranging from .62 to .88 for outcome scores (verbal memory, visual memory, processing speed, and reaction time) (Iverson, Lovell, & Collins, 2003). ImPACT also assesses current symptom reports via the Post-Concussion Symptoms Scale (PCSS), which is a 22-item 7-point Likert symptom inventory and yields a total symptom score. The reliability and validity of the PCSS has been well documented in previous studies (Lovell & Collins, 1999; Pardini et al., 2004)

VO_2 Max: Maximal oxygen consumption (VO_2max) will be assessed with participants wearing a heart rate monitor to continuously measure heart rate (Polar, Lake Success, NY), and we will collect expired air through a Hans-Rudolph mouthpiece integrated with a calibrated metabolic cart (ParvoMedics, Sandy, UT). To ensure all expired air is collected, participants will wear a nose clip. Participants will cycle on an electronically braked cycle ergometer (RacerMate, Seattle, WA).

Procedure

After obtaining University IRB approval, six college-age intramural and/or club sport athletes who meet the inclusion and exclusion criteria will be recruited. Individuals will complete a health history questionnaire and sign a written informed consent. All participants will then complete a baseline ImPACT test. Over the next three weeks, individuals will be administered a VO_2 max cycle ergometer test followed by an assigned 5, 15, or 30 minute rest interval and then re-administered ImPACT.

Each individual will complete three weekly VO_2max tests and will be assigned recovery times (5, 15, and 30 minutes) in a randomized, counterbalanced order. Before beginning the VO2 max test participants will sit on the bike at rest for two minutes. Next, participants will cycle at a comfortable pace (~70 rpm) for at 2 minutes with 50 Watts resistance. Resistance is then increased to 150W for two minutes. Each successive 2 minutes, researchers will increase resistance by 25 Watts. The resistance will begin at the same intensity for all tests, and the ergometer assumes volitional exhaustion when the participant can no longer pedal at a minimum of 30 rpm. Testing will continue until a plateau in oxygen consumption is reached, estimated maximal heart rate is reached (220-age) and/or volitional exhaustion occurs. Participants will be asked to self-report rating of perceived exertion (RPE) prior to increasing resistance during each stage and immediately following VO_2max testing. VO_2max will be defined as the average of the 15-sec values measured within the software of the metabolic cart during the last minute of testing. The participant will recover actively for 2 minutes and then be helped off of the bike to take the CNT after the assigned recovery time has elapsed.

Results

Immediately following maximal exertion negative composite scores, relative to baseline, were seen in 1/6 for verbal memory, 2/6 for visual memory, 2/6 participants for Visual motor, and 2/6 participants for reaction time. Post-test 15 minutes decrements were seen for 0/6 participants for verbal memory, 2/6 participants for visual memory, 1/6 participants for visual motor, and 2/6 participants for reaction time. Post-test 30 minutes decrements were seen for 1/6 participants for verbal memory, 1/6 participants for visual memory, 1/6 participants for visual memory, and 3/6 participants for reaction time. See Table 1.

Discussion

This project is still in need of further research but the pilot gave insight into the aspects of recruitment, data collection, and management.

Time constraints, schedule conflicts, and participant availability was a major barrier to recruitment efforts. Instead of recruiting the proposed number of participants the researcher was only able to enroll six participants. Data collection and management was very straight forward. Setting up and administering the VO2 maximal exertion test is the hardest part of data collection. It should also be noted that clean data collection is not easy, as participant compliance is hard to control. During the pilot a couple of the participants quit exercising before reaching termination criteria. Other individuals did not refrain from caffeine consumption prior to testing. The data collected in this pilot study did not reflect Covassin's research (2007), nor did it support the hypothesis proposed by the researcher. Substantial negative affects after maximal exercise were not obvious. It should be noted that because of the small participant sample statistical measures could not be conducted. Despite these limitations, the researcher gained knowledge that can further help to construct and develop this study. In moving forward, some key considerations should be addressed. First, in order to further limit practice effects the baseline test should be counterbalanced. Administration of this baseline should be randomized like the rest intervals. Second, the mode of exercise should be reconsidered. Many participants mentioned they could have worked harder if they were running. It is important not to discredit this study. Although the pilot did not produce the expected results, the considerations posed above should be explored and a larger sample should be recruited. Appropriate CNT administration protocol is important to help prevent an inaccurate representation of the athlete's baseline neurocognitive function. If maximal exertion negatively impacts baseline scores, as suggested by previous literature, concussions may go undetected.

Baseline													Post-Exertion Immediate (<5 min)																
Subject Number #	Hr of Sleep	PA	Current Mood State	24hr Caloric intake	Caffeine last 24 hours	USG	Motivation (Motiv.)	Verbal Mem	Visual Mem.	Visual Motor	RT	Impulse Control	Hr of Sleep	PA	Current Mood State	24hr Caloric intake	Caffeine last 24 hours	USG	Motiv.	VO2 Max Time	VO2 Max HRmax	VO2 Max RER	VO2 Max RPE	VO2 Max ml/kg	Verbal Mem	Visual Mem.	Visual Motor	RT	Impulse Control
1	7	None	3	2695	Nn	1.015	4	90	80	42.7	0.55	1	7	None	4	3636	No	1.021	4	12:16	173	1.15	20	46.7	99	68	49.35	0.53	2
2	4	Weights	4	2357	No	1.016	4	96	82	45.58	0.51	5	8	Biked	4	2545	No	1.004	4	14:00	196	1.02	19	59.85	97	85	45.38	0.65	7
3	7	Weights	1	2056	Yes	1.014	4	80	64	48.1	0.59	5	7	Weights	2	1820	Yes	1.011	4	12:15	188	1.25	20	50.7	92	71	49	0.49	11
4	8	None	3	2524	No	1.021	3	92	82	40.05	0.61	3	5	None	4	1279	Yes	1.002	3	9:13	185	1.08	20	44.3	79	77	47.88	0.54	5
5	8	None	4	263	No	1.006	3	88	63	37.2	0.56	1	9		5	907	No	1.003	3	7:56	158	1.03	20	41.6	94	81	34.85	0.53	2
6		Walking	3	2633	Yes	1.02	4	85	83	46.08	0.47	4	9	Walking	4	2541	No	1.019	4	8:23	189	1.17	19	51.9	97	95	51.18	0.56	5

Post-Exertion ~15 min																		Post-Exertion ~30 min																
Sub. #	Hr of Sleep	PA	Current Mood State	24hr Caloric intake	Caffeine last 24 hours	USG	Motiv.	VO2 Max Time	VO2 Max HRmax	VO2 Max RER	VO2 Max RPE	VO2 Max ml/kg	Verbal Mem	Visual Mem.	Visual Motor	RT	Impulse Control	Hr of Sleep	PA	Current Mood State	24hr Caloric intake	Caffeine last 24 hours	USG	Motiv.	VO2 Max Time	VO2 Max HRmax	VO2 Max RER	VO2 Max RPE	VO2 Max ml/kg	Verbal Mem	Visual Mem.	Visual Motor	RT	Impulse Control
1	7	None	3	3486	No	1.016	4	14:00	191	1.05	20	55.08	96	89	47.55	0.54	3	8	None	4	2464	Yes	1.016	4	12:27	179	1.12	20	44.7	96	83	50.05	0.55	4
2	9	Walking	4	1539	No	1.005	4	14:45	197	1.16	19	54.1	99	93	45.8	0.53	10	7	None	5	2053	Yes	1.002	4	14:12	201	1.16	20	56	93	89	43.33	0.57	15
3	7	Weights	2	2366	Yes	1.01	4	10:57	184	1.16	20	50.9	90	66	50.33	0.52	5	7	Weights	1	1953	Yes	1.006	4	11:16	188	1.13	18	48.8	94	73	51.88	0.52	8
4	9	None	3	1962	Yes	1.009	3	9:08	185	1.09	19	42.98	92	71	47.13	0.6	8	8	Walking	2	2285	No	1.013	3	9:00	199	1.13	20	46.1	99	82	46	0.63	7
5	8	None	4	822	No	1.004	4	10:12	180	1.06	20	52.8	89	64	34.92	0.53	1																	
	8	None	3	585	No	1.015	3	12:31	176	1.07	20	47.6	97	95	51.18	0.56	5																	
6	7	Walking	4	1836	No	1.007	3	6:45	185	1.25	20	49.5	86	92	48.55	0.52	3	7	Walking	4	1060	No	1.018	3.5	8:30	176	1.15	19	52.6	99	78	46.85	0.54	9

Table 1: PA= Physical Activity prior to the testing. Current mood state is based on a scale of 1-9; 1-Excellent, 2-Very,very good, 3-Very good, 4-Good, 5- Neither good or bad, 6-Bad, 7-Very bad, 8- Very, very bad, 9-Terrible. USG=Urine Specific Gravity. Motiv= Motivation Survey; 1-No Effort, 2-Low Average effort, 3-Average Effort, 4- High Effort. Verbal Mem= Verbal Memory Composite Score ImPACT. Visual Mem= Visual Memory Composite Score. Visual Motor= Visual Motor Composite Score. RT= Reaction Time. Impulse Control= Impulse Control Composite Score.

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