THE EFFECTS OF PHYSICAL AND COGNITIVE ACTIVITY LEVELS POST-CONCUSSION ON RECOVERY

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ABSTRACT

Ashley Cameron Littleton: The effects of physical and cognitive activity levels post-concussion on recovery
(Under the direction of Kevin M. Guskiewicz)

Context: The current recommendation for the management of sport-related concussions is rest, both physical and cognitive. The efficacy of rest in promoting recovery post-concussion is unclear. **Objective:** To characterize the effect of cognitive activity on recovery following concussion, and determine the relationship between patient characteristics and recovery. **Participants:** Forty high school athletes diagnosed with concussions were enrolled in the study (20 standard-of-care, 20 intervention, 27 males, 13 females, age: 15.7 ± 1.1, height: 175.3 ± 9.1 cm, weight: 69.5 ± 34.2 kg). **Interventions:** Participants were administered baseline testing on measures of concussion symptoms, neurocognition, postural control and vision. Two schools were randomly assigned to the intervention group and two schools were assigned to the standard-of-care group. Participant assignments were based on school. Both groups recorded their physical and cognitive activity from the time of injury until they were deemed recovered. Intervention group participants received instructions on how much cognitive activity to complete on a daily basis; standard-of-care participants followed recommendations given by their health care providers. **Main Outcome Measures:** Days to recovery, patient satisfaction, amount and intensity of school-related cognitive activity, sex, age, history of concussion, average cognitive activity per day, average physical activity per day and modifiers of concussion. **Results:** There were no statistically significant differences in the days to recovery (standard of care: 9.10 ± 4.38, intervention: 11.45 ± 5.04; p=0.12) or patient satisfaction (t_{33}=0.24, p=0.53) between the standard-of-care and intervention group. None of the following variables were predictors of recovery: sex, age, previous history of concussion, cumulative cognitive activity, cumulative physical activity, symptoms at the time of injury, or premorbid conditions ($p>0.05$ for all). There were no statistically significant associations between the amount or intensity of a session of cognitive activity and an increase in symptoms ($p>0.05$). **Conclusions:** Although cognitive rest is widely recommended following concussion, in this study, a gradual return to school-related cognitive activity intervention did not provide evidence of a benefit.

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CHAPTER I

INTRODUCTION

Background

Sport-related concussions are a public health concern with up to 3.8 million traumatic brain injuries occurring in sport and recreational activity every year in the United States.[1] Concussions are a form of traumatic brain injury, defined as a "complex pathophysiological process affecting the brain, induced by biomechanical forces"[2] that often results in a series of symptoms. The most common symptoms include headache, dizziness, sensitivity to light and noise, feeling mentally foggy and difficulty concentrating.[3,4] Concussions also typically result in neurocognitive and balance deficits. Given these potential deficits, a greater susceptibility to injury, and a longer recovery period, concussion is of particular concern for younger athletes.[5-9] In addition, young athletes may have more severe consequences following concussion, because their brains are not yet fully developed.[10]

Current management of concussion includes a multifaceted approach taking symptoms, cognition and balance into account. The basis of concussion management includes both physical and cognitive rest until concussion symptoms resolve. Published evidence evaluating the effect of rest following concussion is sparse. There are few specific recommendations for physical or cognitive rest. Instead, clinicians are instructed to take a "sensible approach that involves a gradual return to school and social activities".[2] More research evaluating the effects of rest and gradual progression back to activities of daily living following concussion is needed.

Signs and symptoms of concussion can make participating in school very difficult; therefore, academic accommodations, such as rest breaks or extra time for assignments and tests, are suggested.[11] Concussion symptoms such as feeling in a "fog" and difficulty concentrating or remembering can have negative consequences in an academic setting because school requires concentration and working memory, placing extra neurometabolic demands on a healing brain.[12] Upon returning to school, seventy percent of students recovering from a concussion need some form of support (e.g. more rest breaks, or extended time on assignments) according to their parents.[12] Thirty-eight percent of those same parents worried that their child's grades had been or would be affected by the concussion.[12] The stress associated with returning to normal functional activities before the patient is ready to do so, may lead to the development of post-concussion complaints and reappearance or worsening of symptoms.[13] While academic accommodations are thought to be effective, little is known about the amount and intensity of activity that individuals should perform throughout various stages of the recovery process. Additionally, there is some evidence that receiving or following recommendations for cognitive rest results in no difference in recovery time, and may actually result in longer recovery time.[14,15] Therefore, the effectiveness of academic accommodations in promoting recovery following concussion is still unknown.

Physical rest is also suggested following concussion. Physical rest can decrease concussion symptoms and improve cognition, regardless of the amount of time between the concussion and prescribed rest.[16] High levels of physical activity post-concussion are thought to be the most detrimental. However, there is some evidence that moderate levels of activity may actually result in the best outcome.[17] In order to prevent subsequent re-injury and long-term consequences of concussion, a graduated return to play protocol[2] has been recommended. Only one study has examined the Zurich guidelines [18] for return to play; the study found the guidelines to be safe and successful.[19] The return to play protocol[2] provides structure to resuming physical activity, but the protocol lacks proper validation. Therefore, the optimal amount of physical rest, type of physical rest and the long-term outcomes of rest warrant further investigation.

High school athletes take longer than college athletes or adults to recover from concussions,[7-9] making proper management of concussion in this population extremely important. Physical and cognitive rest have been suggested as a treatment following concussion, yet specific recommendations for implementing these management strategies to limit physical and cognitive activity have not been created. Similarly, the efficacy of physical and cognitive rest has yet to be established. A prospective study examining the role of various levels physical and cognitive activity in the recovery process following concussion is necessary to establish and implement evidence based management protocols. Therefore, the purpose of this study was to characterize the effect of cognitive activity on recovery following concussion. A secondary purpose was to determine the relationship between patient characteristics and recovery.

Specific Aims

1. To characterize the effect of group (standard-of-care vs. cognitive activity intervention) on days to recovery and patient satisfaction following concussion.
2. To determine the association between amount and intensity of school-related cognitive activity and acute increase in concussion symptoms.
    a. To determine the association between length of a session of school-related cognitive activity and an increase in concussion symptoms from pre-session to post-session.

    b. To determine the association between intensity of a session of school-related cognitive activity and an increase in concussion symptoms from pre-session to post-session.

3. To determine the relationship between recovery and sex, age, history of concussion, average cognitive activity per day, average physical activity per day, symptoms at the time of injury and premorbid conditions.

Variables

Independent Variables

1. Specific Aim 1: effect of group on days to recovery and patient satisfaction following concussion
    a. Group
        i. Standard-of-care
        ii. Cognitive activity intervention
2. Specific Aim 2: association between amount and intensity of school-related cognitive activity and change in concussion symptoms
    a. Amount of school-related cognitive activity (continuous, expressed in minutes)
    b. Intensity of school-related cognitive activity
        i. Low (passive activities, such as watching a movie or listening to a lecture)
        ii. High (active activities, such as reading or taking a test or quiz)
3. Specific Aim 3: predicting days to recovery
    a. Sex

i. Male

ii. Female

b. Age (dichotomous)

i. 14-15

ii. 16-18

c. History of concussion (dichotomous)

i. 0

ii. 1 or more

d. Average Cognitive Activity Per Day

i. Sum of length of all sessions of cognitive activity, in minutes, divided by the number of days from the time of injury until the patient was deemed recovered

e. Average Physical Activity Per Day

i. Sum of energy expenditure for all days from injury to recovery obtained from the Physical Activity Questionnaire[20] , divided by the number of days from the time of injury until the patient was deemed recovered

f. Symptoms at the time of injury

i. Total symptom score from the SCAT3 symptom checklist within 24 hours of the injury occurring

g. Premorbid conditions

i. Dichotomous

1. No

2. Yes- self-reported history of any of the following

a. Learning disability

b. Attention deficit hyperactivity disorder (ADHD)

c. History of migraines, epilepsy, seizures or any psychiatric condition

Dependent Variables

1. Specific Aim 1: effect of group (standard-of-care vs. cognitive activity intervention) on days to recovery and patient satisfaction following concussion
   a. Days to recovery
   b. Patient satisfaction survey total score
2. Specific Aim 2: association between amount and intensity of school-related cognitive activity and acute change in concussion symptoms
   a. Change in concussion symptoms
      ii. No change or decrease during session
      iii. Increase during session
3. Specific Aim 3: predicting days to recovery
   a. Days to recovery

Research Hypotheses

1. Specific Aim 1: To characterize the effect of group (standard-of-care vs. cognitive activity intervention) on days to recovery and patient satisfaction following concussion.
   a. The intervention group will recover in fewer days than the standard-of-care group.

    b. The intervention group will have higher patient satisfaction scores, indicating more satisfaction with care, than the standard-of-care group.

2. Specific Aim 2: To determine the association between amount and intensity of school-related cognitive activity and acute increase in concussion symptoms.
    a. There will be an association between the amount of school-related cognitive activity and acute increase in concussion symptoms, with a high amount of cognitive activity being more likely to result in an increase in symptoms.
    b. There will be an association between the intensity of school-related cognitive activity and acute increase in concussion symptoms, with a high intensity cognitive activity being more likely to result in an increase in symptoms.
3. Specific Aim 3: To determine the relationship between recovery and sex, age, history of concussion, average cognitive activity per day, average physical activity per day, symptoms at the time of injury and premorbid conditions.
    a. Sex, age, history of concussion, average cognitive activity per day, average physical activity per day, symptoms at the time of injury and premorbid conditions will be significant predictors of days to recovery.

Operational Definitions

I. *Days to recovery*- Days to recovery was defined as days from the time of injury, until the individual met all of the following conditions
    a. Maintained baseline symptom score on SCAT3 for at least 24 hours, without taking any medications that were prescribed for concussion symptoms

b. Performed within 95% of baseline performance on the SCAT3 (SAC total score and BESS total score), King-Devick test and near-point convergence

c. Performed within the 95% reliable change index (RCI) when comparing post-injury assessments to baseline assessments on all CNS Vital Signs domains and performs within the 80% RCI on at least 6 of the 8 neurocognitive domains

II. *Intervention*- The cognitive activity intervention recommended the amount of cognitive activity that the participant completed on a daily basis. The participant began with the first stage of the intervention and progressed from one stage of the intervention to the next, once he or she was able to complete that stage without a significant increase in symptoms. The intervention is included in Appendix B.

III. *Standard-of-Care*- The standard-of-care group still reported the amount and intensity of cognitive activity that they completed on a daily basis, but they did not receive information from anyone other than their physician and health care providers about the amount of cognitive activity to complete on a daily basis.

IV. *Session*- A session was defined as a sustained period of school-related cognitive activity (i.e. a class or homework) during which work for a single class was completed.

V. *Amount of school-related cognitive activity*- Participants recorded the length of each session of school-related cognitive activity that they complete on a daily basis from the time of injury until they were deemed recovered.

VI. *Intensity of school-related cognitive activity*- Participants recorded the type of school-related cognitive activity that they complete on a daily basis from the time of injury until they are deemed recovered. The type of cognitive activity was used to determine the intensity of cognitive activity based on the scale below.

a. Low- passive activities, such as listening to a lecture or watching a movie
b. High- active activities, such as writing papers, reading for comprehension or group work

Assumptions

1. Participants were honest and truthful in their reporting of symptoms, physical activity and cognitive activity.
2. Participants put forth their full effort on the neurocognitive, postural control and vision tests.
3. Participants did not allow their group assignment to alter how they felt or performed.
4. Physicians did not let group assignment affect clinical decision-making.
5. The standard-of-care group was not assigned comparable restrictions to the intervention group by their physician.

Limitations

1. Progression through the intervention, and determination of assessment time points were based solely on participants' assessment of symptoms.
2. Randomization to group occurred by school and there may be inherent differences between the various schools that could affect results.
3. Results from this study may not apply to other populations, such as collegiate athletes, or non-athletic populations.

4. We did not collect information about what recommendations were given to individuals in the standard-of-care group pertaining to physical and cognitive rest.
5. Participants in the intervention group were not entirely compliant with the recommendations given to them about cognitive activity.
6. We may have had insufficient power to analyze some of our aims.

Delimitations

1. Only concussions that occurred to students at one of four high schools over the course of one academic year were used for this study.
2. Students were only followed on the majority of measures until they were deemed "recovered" using objective measurements. There was no assessment of long-term outcomes.

Significance of the Study

The purpose of this study was to characterize the effect of cognitive activity on recovery following concussion. A secondary purpose was to determine the relationship between patient characteristics and recovery. Physical rest and cognitive rest have been suggested for the acute management of concussion. However, cognitive "rest" has yet to be clinically defined. Furthermore, the influence of physical and cognitive rest on days to recovery following concussion has not yet been established. If a cognitive activity intervention is effective in promoting recovery, then clear guidelines for returning to academics following concussion can be made. Additionally, with improved evidence and a clarified paradigm, schools may be more receptive to providing accommodations for students following concussion. Overall, this may promote speedier recoveries following concussion, while potentially alleviating the stress of returning to the classroom. If the cognitive activity intervention does not promote recovery, then other factors that influence recovery may be identified, and current recommendations for cognitive rest can be modified.

CHAPTER II

REVIEW OF LITERATURE

Introduction

It is estimated that over three million traumatic brain injuries occur each year in the United States, caused by sport and recreational activity alone.[1] Concussions are a form of traumatic brain injury, defined as a "complex pathophysiological process affecting the brain, induced by biomechanical forces".[2] Concussions result in a series of signs and symptoms, with the most common including headache, dizziness, sensitivity to light and noise, feeling mentally foggy and difficulty concentrating.[3,4] Sport-related concussion is of particular concern for younger athletes, because adolescents are more susceptible to concussion,[5,6] and typically take longer to recover.[7-9] Consequences of concussion are thought to be more severe in youth athletes, because their brains are not yet fully developed.[10]

The rate of sport-related concussion has been rising over the past decade. This increase in the incidence of sport-related concussion may reflect increased awareness of concussion, because of education of the general public, or differences in data collection methods.[5,21,22] Recent estimates state that concussions account for 6% of all collegiate athletic injuries and 9% of all high school athletic injuries.[5] At the high school level, the concussion rate is between 2.3 and 2.5 concussions per 10,000 athlete-exposures, defined as one athlete participating in one athletic practice or competition.[22] Concussion rates vary across sports, types of events and sex. Football accounts for the highest rate of concussion, followed by boy's ice hockey and boy's lacrosse.[5,21,22] Concussions are more common in games or competitions than practices, and the most common mechanism of injury is contact with another person.[5,21,22] Females are more likely to sustain a concussion than males in sports in which the rules are similar for both males and females.[5,21-23] Theories for the higher rate of concussion in females include gender differences in cervical spine kinematics and neuromuscular control.[24]

Most athletes recover from a concussion in two weeks, but a subset of the population may take longer.[25] While most college athletes who sustain a sport-related concussion recover within 7-10 days, most high school athletes take 10-14 days to recover.[25] Prolonged recovery, greater than 14 days, occurs in about ten percent of the population.[26] Several factors may affect recovery, including the age of the patient, the number, duration and severity of symptoms, the frequency and timing of previous concussions, comorbidities and premorbidities (including migraine, depression, attention deficit hyperactivity disorders, learning disabilities) and medications (specifically psychoactive drugs and anticoagulants).[2] Identifying those that are more susceptible to concussion may provide one avenue for decreasing concussion rates. Another method for preventing concussion is to identify biomechanics that place athletes at an increased risk of injury.

Biomechanics of Concussion

In an attempt to further understand concussions and potential prevention efforts, the biomechanics of concussions has been researched in a number of settings. Unfortunately, the influence of biomechanical factors on outcomes following sport-related concussion remains inconclusive. Biomechanical studies range from animal models to real-time in vivo models using accelerometers. Animal research has demonstrated that focal brain damage is more likely caused by translational mechanisms, while diffuse axonal injuries are more likely caused by rotational mechanisms.[27] Rotational mechanisms are also more likely to result in loss of consciousness than linear mechanisms.[27] In order to further understand concussion biomechanics, a hybrid III anthropometric device equipped with accelerometers was developed.[28] A subset of impacts that resulted in concussion, observed in National Football League video footage, were reconstructed using two helmeted hybrid III dummies and the same impact velocity, direction and head kinematics observed in the video.[28] Findings suggested that concussions have an injury threshold of 70g to 75g.[28] In order to build upon these findings, a finite element model was used to replicate the average sized adult male head.[29] Using the finite element model, it was estimated that the probability of sustaining a mild traumatic brain injury was 25% for a maximum resultant rotational acceleration of 4,600 rad/sec^2, 50% for 5,900 rad/sec^2 and 80% for 7,900 rad/sec^2.[29] While these studies provide a basis for understanding the biomechanics of concussion, they have their limitations and may not be applicable to human models.

In order to gain an understanding of real-time head impact biomechanics in helmeted athletes, the Head Impact Telemetry (HIT) System was designed. Helmets are equipped with six spring-loaded single-axis accelerometers, that time-stamp, encode and relay impact data to a nearby laptop computer for storage.[30,31] Since the development of the HIT System, a number of researchers have examined real-time head impact biomechanics at both the college and high school level. Generally, the studies have suggested that concussions can occur from a wide-range of impact magnitudes.[32,33] Impact magnitudes also seem to have little to do with the clinical presentation of the injury.[32,33] Biomechanics have been associated with head impact severity. Specifically, the ability to anticipate a collision,[34] and improved visual and sensory performance[35] may aid in minimizing head impact severity. Therefore, instructing athletes to focus on keeping their "heads up" and improving visual and sensory performance may help prevent more severe head impacts. While some concussions can be prevented, some concussions are unavoidable. Therefore, understanding the physiological process that occurs following concussion and appropriate management strategies is important.

Neurometabolic Cascade Following Concussion

Brain injuries that occur in sport can be classified as either focal or diffuse. Focal brain injuries are typically more severe, and usually result from a direct blow that causes damage to cerebral substances and vessels. Examples of focal brain injuries include macroscopic lesions, such as cortical or subcortical brain contusions, and intracerebral hematomas.[36] Diffuse injuries are caused by a linear impact, rotational impact or a combination of linear and rotational impacts. An example of a diffuse brain injury is a concussion. Concussions are often the result of sudden acceleration or deceleration of the head, which causes compressive shear and tensile stress to cerebral tissue.

The physiological response to concussion results in a neurometabolic cascade, sometimes referred to as an "energy crisis" in the brain. Initially, the rapid acceleration and deceleration of the head, associated with the injury, causes stress to cerebral tissue. The stress to cerebral tissue often results in shearing of white matter within the cortex to the midbrain and brainstem.[36] Additionally, the mechanical trauma associated with concussion can cause cell membranes and axons to be stretched.[37] The neurometabolic cascade is initiated when neurotransmitters, such as glutamate, release receptors that open ionic channels immediately after brain injury.[36,38] This leads to the accumulation of extracellular potassium and intracellular calcium, which in more severe cases can lead to cell death.[39] The sodium-potassium pump requires more adenosine-triphosphate (ATP) than usual, causing an increase in the glucose metabolism, and lack of glucose availability. This lack of glucose availability is the most likely explanation for the brain's vulnerability to subsequent injury immediately following a previous head injury.[38] Decreased glucose levels lead to mitochondrial dysfunction, resulting in the use of glycolytic pathways for energy. The use of glycolytic pathways causes lactate accumulation, leading to acidosis, and ultimately ion disequilibrium and cerebral edema. These physiologic changes present themselves clinically as post-concussive signs and symptoms, deficits in postural stability and neurocognitive deficits.

The "energy crisis" that occurs in the brain following concussion can have serious adverse effects on brain functioning. The human brain depends on glucose as its main source of energy, so tight regulation of glucose metabolism is necessary for the brain to function properly. Specifically, glucose metabolism in the brain is necessary for information processing, learning, and long-term memory formation.[40] A lack of glucose availability in the brain can cause impaired processing speed, difficulty concentrating, difficulty remembering and fatigue. This explains why concussed patients may have difficulty processing, learning and remembering. Additionally, completing cognitive and physical activities requires glucose. Therefore, cognitive activity and exercise post-concussion may lead to an even greater glucose deficiency in the brain. The neurometabolic cascade, particularly the lack of glucose availability in the brain following concussion is the most likely explanation for the management recommendations of physical and cognitive rest.

The Adolescent Brain

Evidence has established that children and adolescents have an increased vulnerability to the effects of concussion.[7-9] Animal research has demonstrated that younger rodents had an increased susceptibility to brain injury and longer recovery times compared to older rodents.[41] Similarly, high school athletes have a higher incidence of concussion compared to a subset of college athletes who were determined to be more susceptible to concussion.[5,6] Concussed high-school athletes also recover slower than college athletes.[42] In fact, high school athletes with a history of concussion are more likely to take longer than one month to recover compared to those with no history of concussion.[42] Anatomical differences may explain the age discrepancies in vulnerability to concussion and the deleterious effects of concussion.[6] Adolescent athletes have less protection for their developing brains, because they have decreased "neuronal myelination, a greater head-to-body ratio and thinner cranial bones".[6] Another theory for differences between adolescents and adults is the differing stages of development.

High school athletes' brains are still developing, especially in the areas associated with concentration, memory, reasoning and problem solving.[43] Basic cognitive and brain functions are mostly developed by school age, but significant maturation continues throughout puberty and into adulthood.[44] Adolescence is an important time for development, both structurally and functionally. The degree of cortical folding, overall size and regional functional specialization is developed in early childhood.[45] However, throughout childhood and into adolescence, refinements of brain systems continue, including elaboration of dendritic arborization, increased myelination and pruning of synapses.[45] The synaptic pruning process is thought to be responsible for decreases in gray matter volume in the frontal and parietal regions throughout adolescence.[46] These changes represent a critical period of maturation of fronto-striatal circuitry. Basic cognitive processes, such as working memory, are also developed by childhood, but continue to develop throughout adolescence. Adolescents experience an improvement in the ability to manipulate the environment through abstract thought, planning and cognitive flexibility, along with significant reorganization of neural connectivity in the neocortex.[44] There is also improved processing and storing of information, believed to be responsible for the maturation of higher order cognitive abilities.[47] The continued maturation of the brain throughout adolescence is believed to play a role in recovery from injury.

There are conflicting findings concerning the extent of damage following brain injury in younger individuals. There are some theories suggesting that younger brains are actually more resilient and recover more effectively following head injury.[38] For example, younger rats demonstrated more severe initial responses to brain injury, but they continued to perform well on spatial learning tasks following the injury.[48] However, other findings demonstrated that younger individuals exhibited decreased learning following brain injury. Moderately concussed younger rats who were reared in an enriched environment failed to develop increased cortical thickness and enhanced cognitive performance that occurred in non-concussed rats reared in the same environment.[49] Lasting effects of concussions have been demonstrated in high school athletes. High school athletes with a history of two or more concussions performed similarly on neurocognitive testing to athletes who had just experienced a recent concussion.[50] Overall, it seems as though younger athletes may be more vulnerable to concussion and more susceptible to cumulative and lasting effects.

Effects of Concussion

Symptomatology

Signs and symptoms of concussion range from obvious signs, such as loss of consciousness, to self-reported symptoms, including headache and dizziness. The signs and symptoms of concussion can be stratified into a number of clinical domains, including somatic, neurobehavioral and cognitive.[51] Somatic symptoms include headache, nausea, vomiting, balance problems, sensitivity to light and noise and numbness and tingling; neurobehavioral symptoms include sleeping more than usual, drowsiness, fatigue, sadness, nervousness and trouble falling asleep; cognitive symptoms include feeling "slowed down," feeling like "in a fog," difficulty concentrating and difficulty remembering.[51] In order to gain the most precise measurements of symptom variability and detect small changes over time, symptoms should be assessed using a symptom checklist that allows athletes to denote the number and severity of symptoms, typically utilizing some type of Likert scale.[52] A total symptom score can be calculated by summing the responses for each symptom. The total symptom score allows clinicians to monitor progress over time. Some concussion symptoms are more common than others. The most commonly reported symptoms post-concussion include headaches, fatigue, feeling "slowed down," drowsiness, difficulty concentrating, feeling "mentally foggy" and dizziness.[53] The least frequently reported symptoms include nervousness, feeling more emotional, sadness, numbness or tingling and vomiting.[53]

Certain concussion symptoms have been associated with increased recovery times. In high school football players, dizziness at the time of injury, self-reported cognitive decline and migraine headache were associated with prolonged recovery times.[8,54] In high school athletes, more than 3 symptoms, or the presence of unconsciousness, drowsiness, nausea, amnesia or difficulty concentrating at the time of injury were associated with longer recovery times.[55,26] The total symptom score from the Post-Concussion Symptom Scale (PCSS) was associated with the odds of prolonged recovery in a clinical sample of adolescents and young adults.[56] It seems as though symptoms may be useful in predicting the clinical course of concussions, but more research in this area is needed. Symptoms are one of the many important components of the evaluation process, and may aid in management strategies and return to play decisions.

Neurocognitive Effects

Tests of mental status evaluate the immediate neurocognitive effects of concussion, such as alterations in short-term or working memory. There are several methods available for evaluating the mental status and cognitive function of a concussed athlete. The Standardized Assessment of Concussion (SAC) is useful for initially detecting a concussion and tracking recovery during the early stages following injury, but most college athletes will return to baseline performance on the SAC within 48 hours following concussion.[57] After the sideline evaluation, more sophisticated neurocognitive tests should be used. There are several different types of computerized neurocognitive test batteries used by clinicians to assess concussions, including the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), Automated Neuropsychological Assessments Matrix (ANAM), Axon Computerized Concussion Assessment Test (CCAT) powered by CogSport, Concussion Resolution Index (CRI) and Concussion Vital Signs. Typically computerized concussion assessments include a verbal and visual memory component and measures of attention, concentration and reaction time. The cognitive tests included in the computerized assessments have been validated against traditional neurocognitive tests, such as the Hopkins Verbal Learning Test-Revised, the Brief Visuospatial Memory Test-

Revised and the Symbol Search and Digit Symbol-Coding subtests of the Wechsler Adult Intelligence Scale-Third Edition.[58,59]

One of the newer computerized neurocognitive tests is CNS Vital Signs (CNS Vital Signs, LLC, Chapel Hill, NC), available commercially as Concussion Vital Signs. One of the purposes of CNS Vital Signs is to detect changes in neurocognitive performance over time, allowing for assistance in the evaluation of concussion. Some advantages of CNS Vital Signs include millisecond timing, allowing for accurate detection of even small cognitive changes, immediate automated scoring, ease of exporting the scores and randomized presentation of data, allowing for long-term repeated administration of the test. In addition, CNS Vital Signs allows for customized testing, meaning the test administrator can choose which tests to include in each evaluation. A multitude of cognitive domains are included in the assessment and are known to be sensitive to most causes of mild cognitive dysfunction.[58] Results include scores for the following clinical domains: Neurocognitive Index, Composite Memory, Verbal Memory, Visual Memory, Processing Speed, Executive Function, Psychomotor Speed, Reaction Time, Complex Attention, Cognitive Flexibility and Reasoning. In order to detect suboptimal performance or misunderstanding of the directions, CNS Vital Signs also includes criteria that determine whether or not the scores for each of the subtests were valid. The reliability of CNS Vital Signs is moderate, which is comparable to other computerized neurocognitive tests used for the assessment of concussion.[58] Test-retest correlations for the neurocognitive domains on CNS Vital Signs have been demonstrated to range from 0.31 to 0.88[58] and from 0.29 to 0.79.[60] Other computerized tests range from 0.25 to 0.80[60] (Axon Computerized Concussion Assessment Test), 0.39 to 0.61[61] or 0.53 to 0.86[60] (Immediate Post-Concussion Assessment and Cognitive Test), 0.39 to 0.66[61] on Concussion Sentinel and 0.03 to 0.66[61] on the Concussion Resolution Index.

Despite low to moderate test-retest reliability, computerized neurocognitive tests may still be useful in clinical decision making by using reliable change indices.[60]

It is suggested that baseline measures of neurocognitive performance are collected to control for individual pre-injury levels of neurocognition. Due to the variability amongst athletes, if baseline assessments are available, post-injury scores should be compared to baseline scores. Reliable change indices (RCIs) provide a comparison of post-injury and baseline scores that takes measurement error into account, likely allowing for the optimal detection of impairments. RCIs indicate how large of a change in scores may be expected from one testing session to another based on measurement error. Factors other than measurement error, such as cognitive impairment, are believed to be responsible for any change in scores from baseline to post-injury that exceeds the RCI. If baseline scores are not available, and the individual does not have any premorbid neurocognitive or psychiatric conditions, recent data suggest that the use of normative data for post-injury comparisons can be useful for clinical decision making in the college population.[37, 38] The utility of normative data for post-injury comparison in the high school population has yet to be established. Even if baseline measures are not available, it is important to assess neurocognitive functioning, especially since neurocognitive deficits continue to exist despite the resolution of self-reported symptoms.[62]

Most neurocognitive deficits will resolve within one week, but for a subset of the population may last longer.[26] Certain neurocognitive deficits have been found to be associated with longer recovery times, so neurocognitive testing may be helpful throughout the recovery process. For example, decreased performance on a computerized measure of reaction time in concussed high school football athletes was associated with increased recovery time.[8] Similarly, younger concussed athletes took longer to recover on verbal memory, visual memory and reaction time than older concussed athletes.[63] Younger athletes and athletes with impaired reaction time may require more conservative treatment. More research must be completed concerning the ability of neurocognitive deficits to predict recovery, as it may help guide the recovery process.

Postural Control Effects

Deficits in postural stability have also been noted following concussion. Assessment of postural control may include the three main components: somatosensory input, vision and vestibular input. The assessment of postural control often includes an evaluation of balance in static standing, with some alteration of the various inputs to postural control. Somatosensory input can be altered by asking the athlete to stand as still as possible under varying bases of support, such as double-limb stance, tandem stance, single limb stance, or with the addition of an unstable surface. Visual input can be altered by asking the athlete to close their eyes, or by having a visual surround that moves in response to the athlete's movement. More stable athletes are assumed to be able to stand with less postural sway about a central equilibrium point. Postural sway can be measured using force plates or clinical observation methods. When force plates are used to measure postural sway, a larger magnitude of sway is assumed to indicate poorer postural control. If clinical observation measures are used, clinicians commonly denote errors, such as moving the hip into greater than 20 degrees of abduction, which are thought to indicate poorer postural control. Typically, postural control deficits resolve within 3-5 days in athletes.[64]

While using force plates to assess balance continues to be a common technique for clinicians, simpler, cheaper methods have been gaining popularity. Clinical observational methods, such as the Balance Error Scoring System (BESS), require minimal equipment, providing a more practical, cheaper alternative to more sophisticated tests.[65] The BESS is one of the most commonly used concussion assessment tools amongst athletic trainers.[66] The BESS involves three different stances (double leg, single leg and tandem), which are completed twice (once on a firm surface and once on an unstable surface), for a total of six twenty second trials.[65] An Airex medium-density foam pad is commonly used for the unstable surface. For balance in the double leg stance, participants are instructed to stand as tall as possible with hands on iliac crest and eyes closed, while maintaining balance with both feet touching. For the single leg stance, participants are instructed to stand as still as possible with hands on iliac crests and eyes closed, while maintaining balance on their non-dominant limb with their dominant limb in approximately twenty degrees of hip flexion and forty-five degrees of knee flexion. For balance in the tandem stance, participants are instructed to stand heel-to-toe with their non-dominant limb in back, hands on their iliac crests and eyes closed. BESS stances are demonstrated in Figure 2.1. Leg dominance is commonly defined as whichever leg the participant would use to kick a soccer ball for maximum distance. During the assessment, participants are monitored and if they move out of the test position at any point, they should be reminded to return to a stable testing position as soon as possible and continue with the trial. The test takes about five minutes to administer, and errors are recorded for each 20 second trial. Errors include lifting hands off iliac crests, opening eyes, stepping, stumbling or falling, moving the hip into greater than thirty degrees of flexion or abduction, forefoot or heel losing contact with the ground, or remaining out of the testing position for more than five seconds.[67] Errors are summed for firm stance trials, foam stance trials, and total of all six trials. The BESS has been found to be both valid and reliable.[68,69]

Figure 2.1 Conditions for the Balance Error Scoring System (BESS)

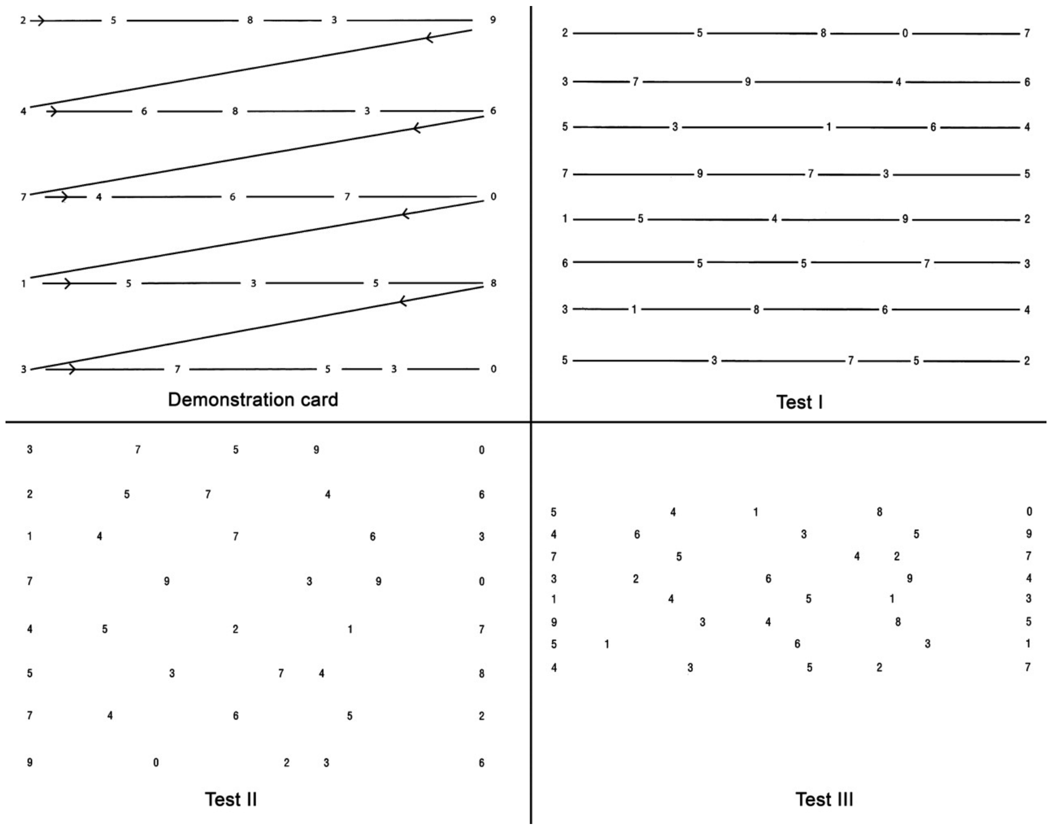
A= firm condition double leg stance, B= firm condition single leg stance (right limb=dominant limb), C= firm condition tandem stance, D= foam condition double leg stance, E= foam condition single leg stance, F= foam condition tandem stance

There are some arguments that the commonly used balance assessments may not be sensitive enough. Most forceplate measures are linear measures, which may not detect subtle changes. Approximate entropy is a nonlinear dynamic measure that has been shown to detect previously unrecognized, subtle physiological changes following concussion.[70] Therefore, it may provide a valuable tool for determining when an athlete is ready to resume play following a concussion. However, approximate entropy requires the use of force plates, which are not available in all settings. Dynamic tasks are more functional, or more representative of what athletes complete in sports, and they may also be more sensitive to concussion. They also do not require the use of force plates. An example of a dynamic task is the tandem gait task, which has been added to the third edition of the Sport Concussion Assessment Tool (SCAT3). For the tandem gait task, participants are instructed to stand with their feet together behind a starting line, then to walk in a forward direction as quickly and accurately as possible.[26] Participants must walk in an alternate foot heel-to-toe gait along a 38 mm wide 3-meter line, ensuring that they approximate their heel and toe on each step.[26] Once the participant crosses the end of the 3-meter line, they turn 180 degrees and walk back to the starting point using the same heel-to-toe gait.[26] Participants re-start the trial if they step off the line, have a separation between their heel and toe, or if they touch or grab the examiner or object.[26] Participants complete a total of 4 trials and the best time is recorded.[26] There is little evidence validating dynamic balance tasks in the assessment of concussion.

While traditional balance assessments take somatosensory input and vestibular input into account, not all assessments effectively evaluate vision. Several aspects of vision can be affected by concussion.[71] For example, vergence, accommodation and saccadic eye movement have all been shown to be impaired following concussion.[72] Binocular vision refers to vision that requires both eyes to be used together. Binocular vision is maintained through vergence, accommodation and saccades. Vergence is the movement of both eyes in opposite directions to obtain or maintain single binocular vision. Accommodation is the adjustment of the eye for varying distances by relaxation or contraction of the ciliary muscles. Saccadic eye movement is a fast movement of both eyes in the same direction. Impaired vergence, accommodation, saccadic eye movement and other visual deficits can make it especially challenging for patients to read and write, which may pose challenges for returning to school. In fact, improvement in vergence, accommodation and saccadic eye movement has been shown to improve reading rate and overall reading ability.[72] Therefore, patients may have difficulty returning to school due to visual deficits caused by their concussion.

Several visual assessments exist, but a recently recognized and commonly used assessment is the King-Devick test. The King-Devick test is a reading efficiency test that has been recommended for sideline diagnosis of sport-related concussion. The King-Devick test provides a rapid assessment of cognitive visual processing and performance.[73] It is easy to administer and only takes a few minutes, making it a useful addition to the traditional concussion evaluation process. During the assessment, participants are asked to rapidly read single-digit numbers from a series of three cards, progressing in difficulty. Participants are asked to read the numbers from left to right and top to bottom as quickly as possibly, without making any errors. The King-Devick test cards are included in Figure 2.2. Concussion has been demonstrated to negatively affect performance on the King-Devick test.[71] Impaired performance on the King-Devick test following concussion was also associated with slower reaction time and visual motor speed.[71] The King-Devick test provides a quick, effective measure of visual processing following concussion.

Figure 2.2 King-Devick test cards



Near-point convergence is another quick and easily administered visual assessment. To determine near point of convergence, typically a patient tracks a high-acuity visual stimulus slowly moving inward along the midline of vision. When the patient reports diplopia or the test administrator notices a break in the fusion of the eyes, the distance of the stimulus from the face is recorded and noted as the near point of convergence.[74 75] Convergence insufficiency has been noted in individuals following traumatic brain injury[76] and may contribute to prolonged visual symptoms following concussion. The evaluation of concussion should include assessments of cognitive visual processing and convergence, as they are necessary for activities of daily living and are often impaired post-concussion.

Multifaceted Approach

It is suggested that a multifaceted evaluation approach is taken following concussion. Clinicians should consider information gained through a thorough clinical examination, and assessment of symptoms, mental status and balance. One of the challenges with concussion management is that there is no “gold standard” for assessment of the injury. In an attempt to create a single all-encompassing measurement for the assessment of concussion, the Sport Concussion Assessment Tool 3 (SCAT3) was developed. The SCAT3 was designed to improve upon previous versions of the SCAT. The literature was reviewed to identify the most sensitive and reliable concussion assessment components of previous versions. The SCAT3 includes more sensitive and reliable components and acts as a clinical tool that allows information to be gained in a uniformed manner, utilizing a multifaceted approach. The SCAT3 includes a basic neurological examination, and an observation of signs of concussion, a symptom checklist, a mental status examination (the Standardized Assessment of Concussion) and a balance assessment (a modified version of the Balance Error Scoring System). The SCAT3 is designed to be a sideline tool for the assessment of concussion, and each of the individual components may be interpreted independently to aid in concussion evaluation.[26] Currently, there is no evidence to support the use of the single composite score in concussion assessment. Regardless of whether or not clinicians use the SCAT3 as part of their concussion assessment, consensus statements emphasize that clinicians should assess a variety of domains, such as symptoms, neurocognition and balance in athletes with suspected concussions.

Postconcussion Syndrome

While the majority of athletes will recover from a concussion within 1 to 2 weeks, some patients will experience postconcussion syndrome. Postconcussion syndrome can be described as a syndrome consisting of a complex mixture of physical, cognitive and behavioral symptoms that persist for an extended period of time following a concussion, but there is no universally agreed upon definition.[77 78] The lack of an agreed upon definition or cause of postconcussion syndrome may be the reason there is also a lack of agreed upon clinical decisions or treatments for the disorder. There is some evidence that the severity of injury may predict post-concussion symptoms, but how to intervene in these severe cases is unclear.[79] A number of researchers have suggested that postconcussion syndrome is merely postconcussion symptoms caused by psychological illness secondary to the brain injury itself.[80] There are also no identified biological differences between postconcussion syndrome and posttraumatic stress disorder.[81] Therefore, psychological illness should be ruled out following brain injury, especially in those who are taking a long time to recover. Appropriate management of concussion in an attempt to minimize stress may aid in preventing psychological effects following concussion.

Psychological Effects

Concussion can lead to a series of psychological effects, which may delay recovery. Concussion may lead to increased stress and an emotional "under-arousal" in some individuals.[82] It is hypothesized that the "under-arousal" is associated with disruption of the ventromedial prefrontal cortex.[82] This "under-arousal" is thought to be responsible for difficulty returning to every day life. For example, students with concussion may have difficulty physiologically responding to or appraising stressful experiences compared to their peers.[82] It is especially important to attempt to reduce stress following concussion, because the stress of returning to every day activities too soon following concussion may lead to the development of post-concussion complaints and reappearance or worsening of symptoms.[13] If students attempt to return to school or sports before they are ready to do so, without proper support, it could delay their recovery from concussion.

Another cause for delayed recovery time following concussion is secondary symptoms, such as depression.[83] Depression may be caused by neuronal changes in areas of the brain responsible for emotional changes, such as the hippocampus, amygdala, frontal cortex and basal ganglia that occur post-concussion. [83] Neuroimaging studies suggest that an underlying pathophysiological abnormality consistent with a limbic-frontal model of depression may be responsible for depressed mood states following concussion.[84] [85-87] Patients that suffer a traumatic brain injury are at a high risk for developing subsequent major depression.[88] Retired professional players with a history of three or more mild traumatic brain injuries are also at a threefold risk of being diagnosed with clinical depression when compared to those retired athletes with no history of concussion.[89] In those concussion patients who continue to experience symptoms, there is a high level of unemployment and poor quality of life.[90] Psychological aspects may contribute to prolonged recovery and poor long-term outcomes, so they should always be considered following concussion.

Long-term Outcomes

The potential for long-term effects of repetitive concussions has recently been recognized.[91] The majority of research examining the long-term effects of concussions is retrospective in nature. These studies typically use interviews of retired athletes about their medical history, followed by a clinical examination. The most common long-term effects include memory problems, mild cognitive impairment and early onset of probable Alzheimer’s Disease.

Retired professional football players who reported three or more concussions had a 3-fold prevalence of reporting significant memory problems, when compared to retired professional football players with no history of concussion.[92] They also had a 5-fold prevalence of mild cognitive impairment.[92] Retired professional football players, assessed as a whole, had an earlier onset of probable Alzheimer's Disease when compared to the general United States male population.[92] A growing concern is the development of personality, speech and impulse control impairments.

Repetitive brain trauma has also been linked to a "progressive neurological deterioration," known as chronic traumatic encephalopathy (CTE).[93] CTE refers to the presences of tau protein deposits within the cerebral tissue, which is thought to result in neurologic deterioration.[94] CTE has only been observed among individuals with a history of repetitive head trauma,[94] and it is associated with memory problems, changes in personality and impaired speech and gait.[93] While CTE is only found in individuals with a history of head trauma, not all individuals with a history of head trauma develop CTE. It is believed that in some cases, repeated axonal stretching, caused by concussions over time may lead to the initiation of the neurodegenerative cascade associated with CTE.[95] Clinically, CTE develops progressively, but gradually over time. Symptoms of CTE typically appear as a decline in neuronal function in midlife.[93] Often, patients experience cognitive, emotional and behavioral symptoms years after repetitive head trauma.[93] Some of the most concerning symptoms include depression, apathy, suicidal tendencies and difficulty with impulse control.[94] A number of symptoms are associated with CTE, but there remains a lack of any clearly defined clinical criteria for the diagnosis of CTE.

Another competing theory for late-life cognitive impairment following repetitive head injury is diminished cerebral reserve. The cerebral reserve hypothesis predicts an earlier expression of age-related neurodegenerative diseases in individuals with repetitive head trauma, but the clinical manifestations of those diseases does not differ from individuals with the disease and no history of head trauma.[96] This differs from CTE, because CTE is a distinct neurodegenerative disorder with a unique clinical manifestation that is different from age-related neurodegenerative diseases. The diminished cerebral reserve hypothesis suggests that the threshold for clinical expression of diseases like Alzheimer's is lowered, likely due to neuronal cell loss.[96] However, any pathology related to repetitive brain trauma, such as hyperphosphorylated tau, would not affect the neurodegenerative process or disease manifestation.[96] One study examined data from 513 retired NFL players and discovered that the data for 35.1% of the population was indicative of possible cognitive impairment.[96] When the data for those 35% with possible cognitive impairment were compared with a clinical sample of patients diagnosed with MCI, the profile of impairments between the two groups was highly similar.[96] The lack of a unique clinical manifestation in this population suggests that the late-life neurocognitive impairments are the result of diminished cerebral reserve. Regardless of the mechanism involved, late-life neurocognitive impairments may be a concern for individuals who have a history of repetitive head trauma. It is possible that proper treatment of head injuries may help to prevent long-term consequences of concussion.

Management

Current Recommendations

There are several consensus statements outlining the proper management of sport-related concussion.[11,97-99] Currently, the most common recommendation for the management of concussion is rest, both physical and cognitive.[11,97-99] It is believed that returning to activities too soon following concussion may exacerbate symptoms and delay the recovery process.[17] In terms of physical rest, current management strategies focus on removing athletes from sports following concussion, but lack guidance for limiting activities of daily living. Athletes should discontinue their sport until their symptoms resolve and they are evaluated on neurocognition and balance. There is a suggested gradual return to play protocol, but it lacks validation. Similarly, the consensus statement on concussion in sport from the 2012 international conference recognizes that cognitive activities following concussion may exacerbate symptoms and prolong recovery,[100] but does not give specific recommendations on how to limit cognitive activities following concussion, nor any data supporting this suggestion. Cognitive rest is thought to involve limiting activities that require attention and concentration, such as schoolwork or using the computer.[12] It is suggested that symptoms are monitored on at least a daily basis and any activities that are associated with an increase in symptoms should be limited as much as possible.[12] Some suggest that academic accommodations, such as limiting class time or working on a computer, and taking frequent breaks throughout the day may be necessary.[12] While physical and cognitive rest seem paramount to concussion management, there is little evidence supporting these management strategies.

Evidence Supporting Physical Rest

One reason for the lack of evidence supporting activity restrictions following concussion is that it is difficult to measure physical and cognitive activity. The majority of studies supporting rest are animal studies, likely because they are more easily controlled. Animal models have demonstrated an "energy crisis" in the brain following injury.[38] This "energy crisis" could be exacerbated by physical activity, which would require even more energy. An animal model using dogs found that even low levels of exercise resulted in increased metabolic changes, which places more demands on an already compromised brain.[101] Exercise may be especially harmful in warm environments, because rats that were exposed to relatively mild elevations in temperature following head injury exhibited long-term functional consequences of the injury.[102] These studies provide some evidence for the current physical activity restrictions, but the generalizability of these studies to humans may be limited.

In order to study the influence of physical rest in humans, physical activity must be accurately measured. Physical activity can be measured using more sophisticated measures, such as pedometers or accelerometers, or simple, cheaper measures, such as activity diaries. While pedometers and accelerometers provide accurate data about the amount or intensity of physical activity completed throughout the day, they have their limitations. For one, they do not provide any information about the type of activities that were performed throughout the day.[103] Also, pedometers and accelerometers can be costly and there are often compliance issues with participants wearing them throughout the day. Therefore, physical activity diaries or logs may provide a cheap, effective alternative for measuring physical activity. Activity diaries have been used in adolescent patients as a means of measuring compliance with activity restrictions following mild traumatic brain injury.[104] Participants were asked to complete an activity diary shown to be a valid, reliable and useful tool to quantify energy expenditure.[105-107] The diary divided each day into 15-minute intervals and children were asked to document the activity that best described what they were doing for each 15-minute interval using a coding system.[104] Participants were asked to complete the diary prior to bedtime every night.[104] An energy value was assigned to each code and the researchers were able to calculate the energy expenditure for the whole day in kJ/d by taking the child's body weight into account.[104] The activity diary was effective in assessing the activity of the participants, because differences were found between the injured and control group consistent with the restrictions placed on the injured group.[104] Activity diaries may provide the best measure of physical activity in concussed participants, because the diaries are validated, cheap and can be filled out quickly and easily once a day.

There are a few studies examining post-concussion activity levels in humans. Prescribed physical rest seems to be beneficial. Regardless of the amount of time between the concussion and the treatment, prescribed rest decreased concussion symptoms and improved cognition in high school and collegiate athletes.[16] Generally, high levels of physical activity post-concussion are thought to be the most detrimental, and low levels are thought to be the least detrimental. However, there is some evidence that moderate levels of activity may actually result in the best outcome.[17] Student athletes who engaged in moderate levels of physical activity demonstrated the best performance on measures of symptoms and neurocognition compared to student athletes participating in high or low levels of activity.[17] In fact, cycling between periods of excessive activity and complete rest in the first 2 weeks following concussion can predict post-concussion syndrome at 3 and 6 months post-injury.[108] Beyond the acute stage, physical activity may be beneficial. In patients with post-concussion syndrome, graded exercise helps promote recovery.[109-110] It has been established that physical activity plays a role in recovery from concussion, but the amount and type of rest has yet to be determined.

Evidence Supporting Cognitive Rest

While there may be appropriate methods in place for measuring physical activity, there is a need for a measure that more specifically quantifies the amount and intensity of cognitive activity that patients complete on a daily basis. One of the first studies to examine activity levels following concussion took both physical and cognitive activity into account.[17] An activity intensity scale (AIS) was used, which consisted of 5 categories: 0- school activity only, 1- school activity and light activity at home, 2- school activity and sports practice, 4- school activity and participation in a sports game.[17] The AIS was useful in categorizing overall levels of activity, but was more focused on physical activity than cognitive activity. Cognitive activity was never specified, and was always classified solely as “school activity”. In an attempt to learn more about how cognitive activity specifically affects recovery, Brown et al.[111] attempted to categorize cognitive activity post-concussion. They created a cognitive activity scale, which had 5 categories: 0- complete cognitive rest, 1- minimal cognitive activity, 2- moderate cognitive activity, 3- significant cognitive activity and 4- full cognitive activity.[111] The level of cognitive activity was determined by the amount of reading, homework, text message, video game playing, online activity, crossword puzzles or similar activities that the individual performed.[111] While this study[111] provides a preliminary look at the effect of cognitive activity levels on concussion recovery, patients only reported an average of their cognitive activity levels between visits, which sometimes was several weeks. Therefore, it does not assess the acute effects of cognitive activity levels on symptoms or the fluctuation of cognitive activity levels from day to day.

However, it does provide a starting point for measuring cognitive activity levels, since there is currently no direct way of measuring cognitive activity.

The few studies examining cognitive activity in post-concussive patients provide conflicting results. A recent study determined that increased cognitive activity was associated with longer recovery times in concussion patients.[111] The study provided preliminary evidence for cognitive rest, but had several imitations, including the wide range of ages of the participants (ages 8-23), the limited availability of post-concussion neurocognitive scores and the length of time between follow up assessments (typically 3-6 weeks).[111] Conversely, Gibson et al.[15] discovered that recommendations for cognitive rest were not associated with time to concussion symptom resolution. In a sample of 135 patients (ages 8-26), 63% were recommended cognitive rest.[15] Approximately 59% of the patients who were recommended cognitive rest went on to experience prolonged symptoms. However, it is unclear whether or not cognitive rest was recommended to certain patients because their initial symptoms were more severe. The few studies examining cognitive activity post-concussion have several limitations. A prospective study with specific cognitive activity recommendations is necessary in order to determine the efficacy of cognitive rest as a treatment of concussion.

Return to Play

Once that acute stage of the injury is managed, clinicians are tasked with providing recommendations for returning athletes to their respective sports. The return to play process is now a fairly objective process involving a number of steps. A universally accepted return to play protocol only began to be discussed in the late 1990s. In 1998, general guidelines stating that no athlete still suffering from concussion symptoms should return to competition were created.[112] These basic guidelines were developed to avoid cumulative brain damage and second impact syndrome.[112] The guidelines highlighted the idea that not all concussions should be managed the same, and they should not be managed based solely on the "grade" of injury, or how much time had passed since the injury. By 2001, a mere three years later, a return to play protocol following a stepwise process was established.[113] Since 2001, few changes have been made to the return to play protocol. The protocol involves a multifaceted approach taking participants' symptoms and objective measures into account. While the graduated return to play protocol is widely accepted and used, it has not been validated.

Return to play decisions should be made based on a multifaceted evaluation process, taking symptoms, neurocognition and balance into account. Return to play should not be considered until an athlete is completely asymptomatic compared to baseline, and has returned to baseline or normative values on neurocognitive and balance assessments. Return to play should be a gradual process, and athletes should be administered a symptom checklist prior to beginning the return to play protocol in order to be monitored for any return of signs and symptoms throughout the protocol. The advancement of science has allowed for the individualized approach to the return to play (RTP) progression that is based on the individual's symptoms following each stage of the progression.[2]

The gradual return to play process includes a stepwise progression. The athlete proceeds to the next level once they complete a level and remain asymptomatic. Generally, each step should take approximately 24 hours to complete, so that it should take the athlete about one week to advance through the entire progression. If any post-concussion symptoms return, then the athlete should move back to the last asymptomatic level and continue the progression from there. A sample gradual return to play program adapted from the Zurich guidelines is included below (Table 2.1).

Table 2.1 Gradual Return to Play Process

Stage	Functional Exercises
1- No activity	Complete physical and cognitive rest
2- Light Aerobic Activity	Walking, swimming, stationary biking (<70% MHR)
3- Sport specific exercise	Running drills, etc.
4- Non-contact training drills	Passing drills, can begin resistive exercise
5- Full contact practice	Following medical clearance, full practice
6- Return to Play	Return to full participation, including games/competitions

Risk of Re-injury

A history of concussion may be the best predictor of a subsequent concussion. Children with a history of concussion, especially those who sustained one recently, are at an increased risk for prolonged symptoms.[114] College athletes with a history of concussion are more likely to have future concussions than individuals with no previous history.[25] In fact, 6-7% of concussed athletes sustain additional concussions in the same playing season.[25] College athletes with a previous history of concussion also have slower recovery times on neurocognitive functioning.[25] It is hypothesized that the brain's ability to respond to traumatic forces may decrease over time with each subsequent impact, making individuals more susceptible to another concussion. The propensity for subsequent injury and prolonged recovery time following concussion highlights the importance of proper concussion management.

Second impact syndrome is an often-cited consequence of returning to play too soon following concussion. Second impact syndrome has been defined as rapid brain swelling that occurs when an athlete who has sustained an initial head injury sustains a second head injury before the symptoms associated with the first head injury have fully cleared.[112] While second impact syndrome is likely the most severe negative outcome that occurs following concussion, as it is often fatal, it is very rare and evidence supporting the existence of second impact syndrome remains for the most part anecdotal.[115] A recent case study describes a scenario in which imaging is available between the first and second head impact in a football player who suffered second impact syndrome.[116] The imaging from the case study supports the hypothesized model of brain injury in which the dysautoregulation of cerebral blood flow results in massive hyperemia, or increased blood flow.[116] The rapid blood flow dysautoregulation and vascular engorgement is thought to be responsible for fatal or traumatic hyperemic herniation of the brain.[116] The number of athletes that prematurely return to play following concussion without negative consequences is unknown. It is also still unknown why some individuals may suffer second impact syndrome while others may not. It is believed that age may play a role in second impact syndrome, because almost all documented cases have been in high school athletes and adolescents.[116] Second impact syndrome is rare yet serious and often fatal, so clinicians should be aware of the negative consequences of premature return to play.

Return to Academics Following Concussion

Returning to the classroom following concussion may often be overlooked, because it does not result in risk of re-injury or potential second impact syndrome. During the recovery process, high school and college student-athletes often must continue to attend school. This is problematic, because concussions can directly affect learning. Concussions cause fatigue, headaches, blurred vision, sensitivity to light, sensitive to noise, feeling in a “fog” and difficulties with concentration, memory and attention, which can make learning very difficult. If a concussed athlete has a modifier of concussion, such a learning disability, where they already have difficulty paying attention in class, the return to full cognitive activities could be extremely challenging. Approximately 38% of parents with children who had concussions worried that their child’s grades were affected by the concussion.[12] Allowing for some affordances early in the recovery process may allow athletes to recover quicker by eliminating emotional pressure and allowing them to return to a regular workload as soon as possible.[12] Some experts have suggested that students who are struggling academically seek support from the school through excused absences, rest periods, or in more extreme cases response to intervention services or 504 plans.[12] Unfortunately, there is a lack of empirical evidence supporting the efficacy of cognitive rest following concussion. Empirical evidence supporting the need for cognitive rest following concussion is necessary, in order to justify or improve current recommendations.

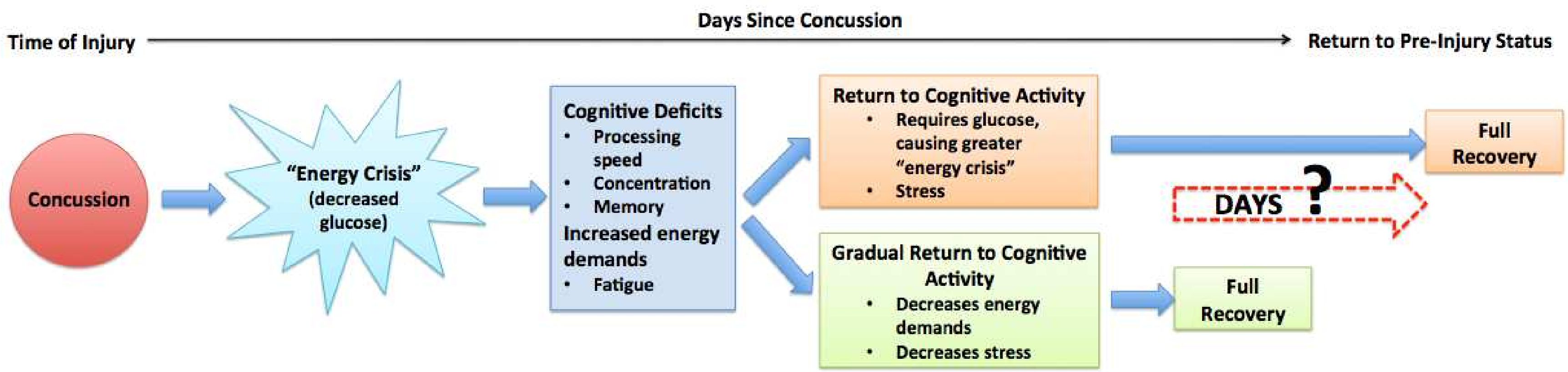
Returning to school and engaging in too much cognitive activity, such as reading or studying too soon may result in increased symptoms and potentially prolonged recovery.[17] It is suggested that an appropriate level of cognitive activity that does not exacerbate or cause the reemergence of symptoms is determined.[117] Therefore, students do not necessarily need to stop school altogether, but could complete half days of school or take extra rest breaks. The tolerable amount of cognitive activity post-concussion is likely different for each individual and changes throughout the recovery process. For example, initially, patients may benefit from almost complete cognitive rest, including discontinuation of computer use, cell phone use, reading, watching television, and playing video games. [118] Later in the recovery process, patients may be able to tolerate light reading or short periods of computer use. While cognitive rest is thought to improve recovery, it is not frequently recommended following concussion.[118] It seems as though more emphasis has been placed on physical rest. In a sample of students who were one month post-concussion, more than 80% reported increased post-concussion symptoms following cognitive exertion, while less than 40% reported an increase in symptoms following physical exertion.[118] This discrepancy could possibly be explained by the restrictions placed on physical and cognitive activity. In the same sample, 43% of the students reported receiving restrictions on physical activity, while only 3% reported receiving restrictions on cognitive activity.[118] Another examination of concussed adolescent athletes revealed that all of the athletes returned to sports without exacerbation of symptoms, but 38.5% experienced new "issues" upon returning to the classroom.[19] This indicates that cognitive activity may be causing an increase in post-concussion symptoms, but it is not being restricted as much as physical activity.

Over the past decade, there has been an increase in education efforts targeting athletes and coaches, concerning concussion. Some legislative efforts have been directed towards outlining necessary education and policies needed for managing concussions in the classroom, but have unfortunately failed.[119] There are several steps directed towards designing and implementing a concussion program in a school. These steps include establishing a policies and procedures document, educating school personnel and implementing plans for students that sustain concussions.[12] Before the school year, the school administration should develop the written concussion management policies and procedures, the school concussion resource team, examine teaching methods to support recovery and develop a list of concussion resources for education, consultation and referral.[12] There should also be a teacher and staff education and training that occurs before the school year, which should be reviewed during the first faculty meeting of the school year.[12] If a student sustains a concussion during the school year, the concussion resource team should be responsible for ongoing in-school observation, monitoring and supports, until the student is cleared for a full return to academics.[12] Having students receive a consistent message from all school staff throughout the course of their recovery may help promote a speedier recovery by reducing cognitive demands and stress.

Summary of Rationale for Study

Physical and cognitive rest are suggested for the management of concussion, yet the influence of physical and cognitive rest on days to recovery has yet to be established. Decreasing cognitive activity is believed to decrease the energy demands placed on a healing brain and decrease stress during the recovery process (Figure 2.3). If altering cognitive activity following concussion is effective in promoting recovery, then clear guidelines for the return to academics process can be made. The purpose of this study was to characterize the effect of cognitive activity on recovery following concussion. A secondary purpose was to determine the relationship between patient characteristics and recovery. If a cognitive activity intervention is effective in promoting recovery following concussion, then clear guidelines for the return to academics process can be made. Additionally, schools may be more receptive to providing accommodations for students following concussion. Overall, this will promote speedier recoveries following concussion, while potentially alleviating the stress of returning to the classroom. If the cognitive activity intervention does not promote recovery, then other factors that may help identify recovery may be identified, and current recommendations for cognitive rest can be modified.

Figure 2.3 Theoretical framework for regulating cognitive activity



Concussion leads to an energy crisis in the brain, caused by a lack of glucose availability. The lack of glucose availability causes cognitive deficits and fatigue. Returning to too much cognitive activity too soon can increase the energy demands on an already "under energized" brain, and increase stress experienced by the patient. The increased energy demands and stress lead to longer recovery times. Providing a gradual return to cognitive activity decreases the energy demands placed on the brain and decreases the stress of the patient, theoretically decreasing recovery time.

CHAPTER III

METHODOLOGY

Study Overview and Design

This is a prospective cohort study with a repeated measures design. This study was aimed at characterizing the effect of cognitive activity on recovery following concussion. A secondary purpose was to determine the relationship between patient characteristics and recovery. Participants underwent pre-season baseline testing on a series of clinical measures, including a sideline assessment, which encompasses a symptom assessment, a mental status assessment and a balance assessment (all part of Sport Concussion Assessment Tool 3), a series of visual assessments (King-Devick test and near-point convergence) and a computerized neurocognitive test (CNS Vital Signs). Participants were assigned to the intervention or standard-of-care group, based upon their school's group assignment. The standard-of-care group received standard-of-care, meaning they followed whatever recommendations they were given by their physician and health care providers. The intervention group received gradual return to cognitive activity guidelines. Participants recorded their physical and cognitive activity on a daily basis following their concussion, until they were deemed recovered. Once participants had been asymptomatic for 24 hours, they were reassessed on baseline measures to determine recovery. Finally, two weeks after the participant was deemed recovered, they completed a patient satisfaction survey.

Study Participants

Forty high school athletes who were diagnosed with a sport-related concussion at one of four high schools over the course of the 2014-2015 academic year were included in the study. Athletes from the following sports were baseline tested prior to participation in sport: football, soccer, field hockey, volleyball, basketball, wrestling, lacrosse, baseball, softball and cheerleading. Institutional Review Board approved informed consent documents were delivered to high school players and their parents/legal custodians at baseline testing.

Procedures

Baseline Testing

Prior to the start of the season, athletes at each of the four high schools were baseline tested on a series of clinical measures. Baseline testing was conducted at the athletes' high school and was administered by athletic trainer and a clinical outreach team. Participants were assessed on a clinical measure of concussion (Sport Concussion Assessment Tool 3, or SCAT3), a series of visual assessments (the King-Devick test and near-point convergence) and a computerized neurocognitive test (CNS Vital Signs), which provided a baseline score on the selected variables. Athletes also completed a demographic information survey.

Post-concussion Measures

Prior to the beginning of the 2014-2015 academic year, two of the four high schools were assigned to the intervention group, and the other two schools were assigned to the standard-of-care group. The standard-of-care group received standard-of-care, meaning they followed whatever recommendations they were given by their physician and health care providers. The intervention group received gradual return to cognitive activity guidelines. All participants, regardless of group, had an initial meeting within 24 hours of their injury. The initial meeting was held in person, or over the phone. During the initial meeting, all participants were given a "Study Workbook," which allowed them to keep track of their symptoms, physical activity and cognitive activity over the next several days to several weeks. Participants were also given the option to complete the Study Workbook online using a series of Qualtrics surveys, or complete the Study Workbook both online and in paper. The online and paper options were given to increase participant compliance, and because the participant may not always have access to the internet.

At the initial meeting, participants in the intervention group were instructed on how much school-related cognitive activity he or she should complete in the next 24 hours, including the amount of work they should complete in a single session, how long of a break they should take between sessions and the maximum amount of total school-work they should complete in the next 24 hours. Participants in the standard-of-care group simply followed instructions given to them by their physician or athletic trainer and were not given any information about how much activity to complete by members of the research team. If there were discrepancies between information given to the participant by their physician and the research team, a member of the research team contacted the physician to discuss the case and gain permission for the individual to participate in the study. In cases where the information given by the physician is more conservative than the information given by the research team, participants were instructed to follow the information given to them by their physician.

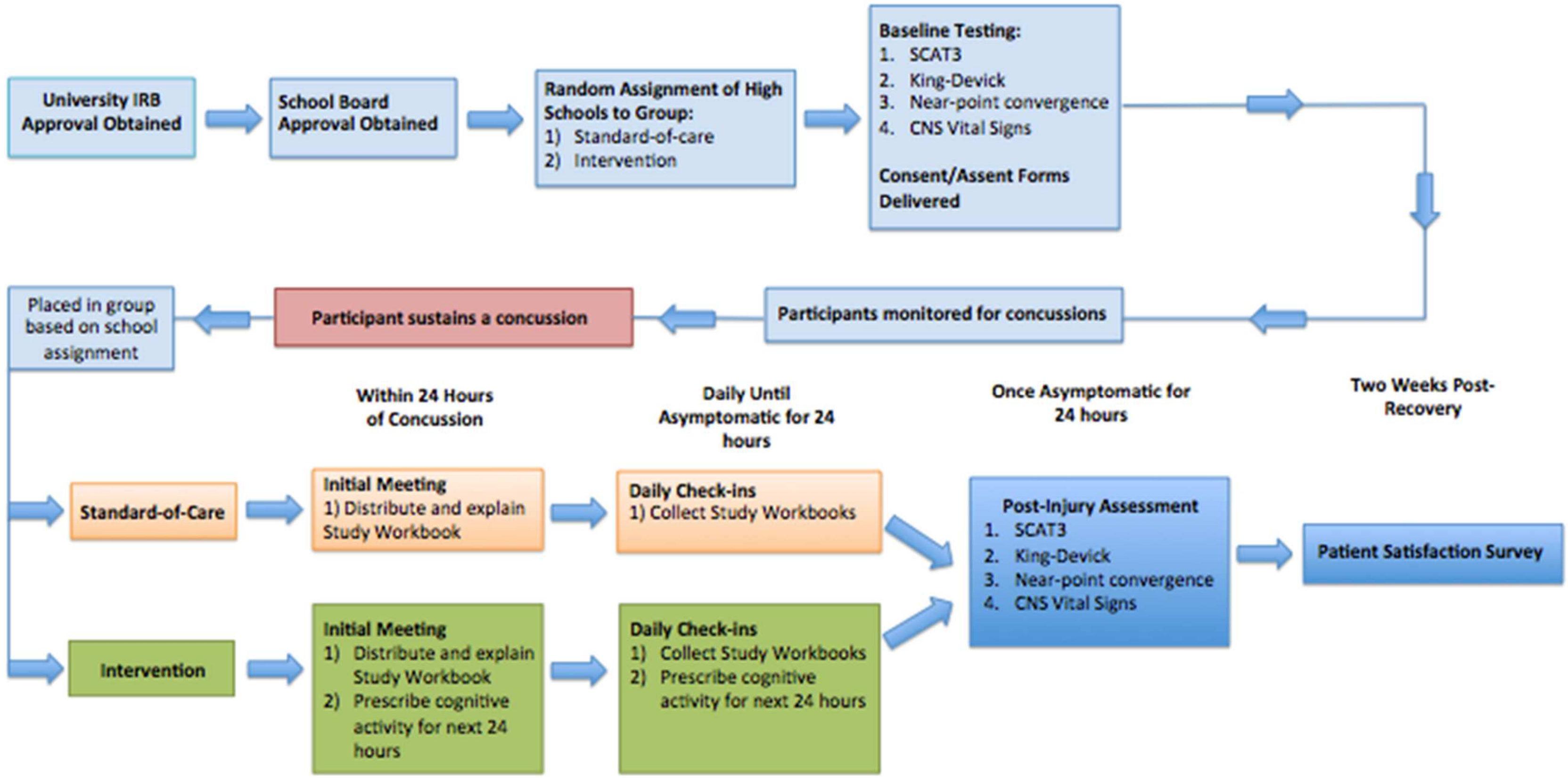
All participants, regardless of group, talked to a member of the research team on a daily basis, either in person or over the phone. These “daily check-ins” were conducted to ensure that the Study Workbooks were being completed properly by the participants, and for identifying when the participant was symptom free (when compared to baseline SCAT3 symptom scores). Once the participant had been symptom free for 24 hours, he or she was administered a post-injury assessment, where they were reassessed on baseline measures (SCAT3, the King-Devick test, near-point convergence and a computerized neurocognitive test, CNS Vital Signs) to determine whether or not they had reached recovery. The post-injury assessments were administered at the participant’s high school by their athletic trainer or a member of the research team.

Days to recovery was defined as number of days from the time of injury until the participant met all of the following conditions: maintained baseline score on SCAT3 symptom score for at least 24 hours without taking any medications that were prescribed for concussion symptoms, performance comparable to baseline (within 95% of baseline performance) on the remaining components of SCAT3, King-Devick test and near-point convergence and performance within 95% of reliable change index when comparing post-injury assessments to baseline assessments on all 8 neurocognitive domains, while performing within 80% of the reliable change index (more conservative) on at least 6 of the 8 neurocognitive domains. If a participant did not meet the criteria for recovery at their post-injury assessment, the participant’s physician determined the timeline for follow-up assessments after the initial post-injury assessment based on the participant’s clinical presentation. Once participants were deemed recovered, they were no longer asked to record their symptoms, physical activity or cognitive activity. They proceeded with activity and a gradual return to sport, under the direction of their physician and athletic trainer. Two weeks after the participants were deemed recovered, they were asked to complete a short, 18 questions patient satisfaction questionnaire. After completion of the patient satisfaction survey, the participant continued to be monitored for re-injury, but otherwise their participation in the study was concluded. Study procedures are summarized in Figure 3.1. A summary of assessment time points is provided in Table 3.1.

Table 3.1 Summary of Assessment Time Points

Measures	Baseline	Daily Post-concussion	Symptom Free for 24 hours	2 Weeks Post Recovery
SCAT3 (Symptom Checklist, SAC, BESS)	X		X	
King-Devick	X		X	
Near point convergence	X		X	
CNS Vital Signs	X		X	
Study Workbook		X		
Patient Satisfaction Survey				X

Figure 3.1 Study procedures



Measurements and Instrumentation

Demographic Information

Demographic information for all participants was collected during baseline testing, and included age, sex, height, weight, academic year, and pertinent medical history (Appendix D).

Sport Concussion Assessment Tool 3 (SCAT3)

The SCAT3 (Appendix E) was administered during baseline and during post-injury assessments. The SCAT3 includes a symptom scale, basic neurological examination, a mental status examination (the Standardized Assessment of Concussion) and a balance function assessment (a modified version of the Balance Error Scoring System or a tandem gait task). It is designed to be a sideline tool for the assessment of concussion and each of the individual components may be interpreted independently to aid in concussion evaluation.[26] Outcome measures for the SCAT3 include a symptom score, a Standardized Assessment of Concussion (SAC) total score, Balance Error Scoring System (BESS) total score, and tandem gait score. Each component of the SCAT3 is described below:

Symptom Scale

The symptom scale asks the participants to score themselves on 22 concussion symptoms based on how they feel at the time of evaluation. The symptoms include: headache, "pressure in head," neck pain, nausea or vomiting, dizziness, blurred vision, balance problems, sensitivity to light, sensitivity to noise, feeling slowed down, feeling like "in a fog," "don't feel right," difficulty concentrating, difficulty remembering, fatigue or low energy, confusion, drowsiness, trouble falling asleep, more emotional, irritability, sadness, and nervous or anxious. The scale includes: 0 (none), 1 and 2 (mild), 3 and 4 (moderate) and 5 and 6 (severe). This allows for a total number of symptoms ranging from 0-22 and a total symptom score, taking severity into account, ranging from 0-132.

Standardized Assessment of Concussion

The Standardized Assessment of Concussion (SAC) is a mental status examination. It includes five components: orientation, immediate memory, concentration and delayed recall. The orientation section is first and includes the following questions:

"What month is it?"

"What is the date today"

"What is the day of the week?"

"What year is it?"

"What time is it right now? (within one hour)"

Each question is worth 1 point, allowing for a total of 5 points in the Orientation section. Next is the immediate memory section. Participants are read a list of 5 words (such as: elbow, apple, carpet, saddle, bubble). Participants are asked to say as many words as they can remember in any order. Participants get one point for each correct word they state. This process is repeated two more times. This allows for three trials in the immediate memory portion for a total of 15 possible points. The next section is concentration, which includes digits backward and months in reverse order. For the digits backward portion, participants are read a string of numbers ranging in length from 3-7 digits (such as 4-9-3 or 7-1-8-4-6-2). Participants are asked to recite the numbers back to the test administrator in reverse order of how they were read to them. There are four strings of numbers, each one increasing in length. Each digit string is worth one point allowing for a total of 4 points for the digit backwards task. For the months in reverse order task, participants are asked to say the months in reverse order beginning with December. The entire sequence is worth one point, meaning that the entire concentration section is worth a total of 5 points. For the delayed recall portion, participants are asked to state any words from the list that they were read a few times earlier that they can recall in any order. Participants received one point for each correct word they remember, allowing for another 5 possible points. There are a total of 30 possible points on the SAC.

Balance Error Scoring System (BESS)

A modified version of the Balance Error Scoring System (BESS) is included in the SCAT3, with the option of completing the full version BESS. The modified version of the BESS only includes the firm stance conditions, while the full version of the BESS includes both the firm stance conditions and the foam stance conditions. For this study, the full version of the BESS was used. The BESS involves three different stances (double leg, single leg and tandem stance), which are completed twice (once on a firm surface and once on an unstable or foam surface), for a total of six twenty second trials.[65] An Airex medium-density foam pad is commonly used for the unstable surface. For balance in the double leg stance, participants are instructed to stand as tall as possible with hands on iliac crest and eyes closed, while maintaining balance with both feet touching. For the single leg stance, participants are instructed to stand as still as possible with hands on iliac crests and eyes closed, while maintaining balance on their non-dominant limb with their dominant limb in approximately twenty degrees of hip flexion and forty-five degrees of knee flexion. For balance in the tandem stance, participants are instructed to stand heel-to-toe with their non-dominant limb in back, hands on their iliac crests and eyes closed. Leg dominance is commonly defined as whichever leg the participant would use to kick a soccer ball for maximum distance. During the assessment, participants were monitored and if they moved out of the test position at any point, they were reminded to return to a stable testing position as soon as possible and continue with the trial. The test takes about five minutes to administer, and errors are recorded for each 20 second trial. Errors include lifting hands off iliac crests, opening eyes, stepping, stumbling or falling, moving the hip into greater than thirty degrees of flexion or abduction, forefoot or heel losing contact with the ground or remaining out of the testing position for more than five seconds.[67] Errors are summed for firm stance trials, foam stance trials, and total of all six trials. The BESS has been found to be both valid and reliable.[68,69]

Computerized Neurocognitive Assessment- CNS Vital Signs

CNS Vital Signs (CNS Vital Signs, LLC, Chapel Hill, NC) consists of a series of computerized neurocognitive tests. One of the purposes of CNSVS is to detect changes in neurocognitive performance over time, allowing for assistance in the evaluation of concussion. CNSVS was administered during baseline testing and post-injury assessments. During all assessments, participants were administered CNSVS in a controlled environment and were given standardized instructions (Appendix F). CNSVS assesses a multitude of cognitive domains and results include scores for the following clinical domains: Neurocognitive Index, Composite Memory, Verbal Memory, Visual Memory, Processing Speed, Executive Function, Psychomotor Speed, Reaction Time, Complex Attention, Cognitive Flexibility and Reasoning.[58] The individual subtests are described in detail by Gualtieri and Johnson, and are included in Appendix G.[58] Main outcome measures include the standard scores for the following clinically relevant domains: Verbal Memory, Visual Memory, Processing Speed, Executive Function, Psychomotor Speed, Reaction Time, Complex Attention, and Cognitive Flexibility. The standard scores place all outcomes on the same scale and provide for an easier clinical understanding. The standard scores are based on a normative dataset that matches participants by age. A standard score of less than 70 is considered a score that indicates a likely deficit or impairment, 70-79 represents a possible moderate deficit and impairment, 80-90 represents a slight deficit and impairment, 91-110 represents normal function and normal capacity, and greater than 100 represents high function and high capacity.

Visual Assessments

The King-Devick test is a reading efficiency test that has been recommended for sideline diagnosis of sport concussion. The King-Devick test provides a rapid assessment of cognitive visual processing and performance.[73] During the King-Devick test, participants were asked to rapidly read single-digit numbers from a series of three cards, progressing in difficulty. Participants were asked to read the numbers from left to right and top to bottom as quickly as possibly, without making any errors. The participants are given a practice card before each of the test cards, to ensure that they understand the directions. The test administrator followed along on the King-Devick scorecards in order to record any errors that the participants make during the test. The King-Devick test has been shown to be valid, reliable and useful in the detection of concussion.[73]

Near-point convergence is another quick and easy to administer visual assessment. To determine near point of convergence, the participant was asked to track a high-acuity visual stimulus slowly moving inward along the midline of vision. When the patient reports diplopia or the test administrator notices a break in the fusion of the eyes, the distance of the stimulus from the face was recorded and noted as the near point of convergence.[74] The participants completed the assessment three times and the average of the three assessments were used for data analysis.

Intervention (Appendix B)

The cognitive activity intervention involved scaling the amount of cognitive activity that the individual participated in on a daily basis. The intervention included 5 stages (Table 3.2). Each stage recommended a certain environment (home or at school), the amount of cognitive activity to be completed in one sitting, the amount of rest to take after each session of cognitive activity and the total amount of cognitive activity to complete in one day. Participants were instructed to complete stage one at home, which included a maximum of 20 minutes of cognitive activity at a time, followed by a 30 minute break, with a total of no more than 1 hour of cognitive activity during the day. If the participant experienced any increase in symptoms while completing cognitive activity, he or she was instructed to stop their activity at that time. Once the participant's symptoms returned to their pre-cognitive activity level, he or she was instructed to take the suggested rest break before beginning any more cognitive activity. Once participants were able to complete the maximum recommended amount of cognitive activity in a given day without any of their sessions of cognitive activity resulting in an overall increase in symptoms greater than 6 or any one symptom increasing greater than 3 points, then he or she could progress to the next stage of the intervention.

Table 3.2 Stages of Intervention

Stage	Environment	Only complete this much cognitive activity in one sitting:	Rest for at least this long following each session of cognitive activity:	Complete no more than a total of this much cognitive activity each day:
1	Home	20 minutes	30 minutes	1 hour
2	Home	45 minutes	20 minutes	3 hours
3	School	2 hours	10 minutes	5 hours
4	School	4 hours	10 minutes	7 hours
5	School	8 hours	--	--

Participants were also given specific recommendations according to the symptoms they were experiencing, based on recommendations of Halstead et al. [120] Participants experiencing headaches were instructed to take frequent breaks throughout the day and to rest in a quiet room if their symptoms increase. Participants with dizziness were instructed to leave each class early in order to allow them extra time to get to the next class. Participants experiencing visual symptoms were instructed to reduce the brightness on their computer or phone screens, wear sunglasses if necessary and to avoid fluorescent lights. Participants experiencing noise sensitivity were instructed to eat lunch in a quiet area with a classmate and to use earplugs if needed. Participants reporting difficulty concentrating or remembering were instructed to postpone all exams. Finally, participants exhibiting sleep disturbances were instructed to allow for a late start to their day so they can catch up on sleep. The stages of the intervention and other recommendations are included in Appendix B.

If there were discrepancies between information given to the participant by their physician and the research team, a member of the research team contacted the physician to discuss the case and gain permission for the participant to participate in the study. In cases where the information given by the physician was more conservative than the information given by the research team, participants was instructed to follow the information given to them by their physician.

The standard-of-care group received the standard of care. Participants in the standard-of-care group still reported their symptoms and the amount and intensity of cognitive activity that they completed on a daily basis via the activity diaries, but they did not receive information from anyone other than their physician and health care providers about the amount of cognitive or physical activity to complete on a daily basis.

Study Workbook (Appendix C)

All participants were asked to complete a Study Workbook every day following their concussion until they were deemed recovered. Participants were given the opportunity to complete the Study Workbook on a series of paper surveys, online using Qualtrics surveys, or through a combination of paper and online surveys. A variety of methods were available to the participants in order to lessen the burden to participants and to increase compliance. The Study Workbook consisted of 2 main surveys, including:

1) Night Time Survey
2) Schoolwork Surveys

Both surveys are described below:

Night Time Survey

Participants were asked to complete the nighttime survey at the end of the day, as close to when they were trying to fall asleep as possible. The nighttime survey took about 5-10 minutes to complete. The nighttime survey consisted of the abbreviated symptom checklist, the 22-item symptom scale from the SCAT3, a physical activity diary and the non-school related cognitive activity diary.

The physical activity diary was completed once at the end of each day, which has been shown to be a valid and reliable means of reporting in a high school population.[104] The activity diary takes both the amount and intensity of activity into account, allowing for a calculation of energy expenditure. Each activity that the participants perform on a daily basis is assigned an energy cost, in METS, from previous studies.[20] This allows for a calculation of energy expenditure per day, controlling for the participant's body weight (kJ/d).

For the non-school related cognitive activity diary, participants were asked to check off whether or not they have completed a series of non-school related cognitive tasks (such as watching television, listening to music, playing video games, texting, surfing the internet or talking on the phone). If participants have completed one of the tasks, they were asked to check whether or not the task was more difficult than it was before they had their concussion. Finally, participants are asked to describe each of the non-school related cognitive activities they completed and to record how long they spent completing that activity.

Schoolwork Surveys

For the pre-schoolwork survey, participants were asked to complete the abbreviated symptom checklist prior to beginning their session of cognitive activity. Next, participants were asked what time they were starting the session of cognitive activity and what the session of cognitive activity would entail.

For the post-schoolwork survey, participants were asked to complete the abbreviated symptoms checklist immediately after concluding their session of cognitive activity. Then, they were asked what time they stopped their cognitive activity and whether the activity was completed at home or at school. Participants were also asked what class the session of cognitive activity was related to (e.g. math, science, or history). They were also asked what activities they completed (e.g. reading, studying, listening to a lecture, taking notes, doing group work), and whether the activity was more difficult that usual.

Patient Satisfaction Survey

Participants were asked to complete the patient satisfaction survey two weeks after they were deemed recovered. The patient satisfaction survey is adapted from the Patient Satisfaction Questionnaire (PSQ-18), which is a publically available scale that measures general patient satisfaction with care. The PSQ-18 was designed based on feedback from patients using input from providers about the care they receive and has been used in various settings.[121,122] The PSQ-18 yields separate scores for each of seven different subscales: general satisfaction, technical quality, interpersonal manner, communication, financial aspects, time spent with doctor, accessibility and convenience. The questions examining the subscales relevant to this study were maintained in the patient satisfaction survey, including general satisfaction, technical quality, communication and time spent with doctor. Questions examining subscales that are not relevant to this study (interpersonal manner, financial aspects, accessibility and convenience) were replaced with questions examining support during the process of returning to school and sports following concussion (Appendix H). Some PSQ-18 items are worded so that agreement reflects satisfaction with medical care, whereas other items are worded so that agreement reflects dissatisfaction with medical care. All items were scored so that high scores reflect satisfaction with medical care (as demonstrated in Appendix I).

Data Reduction

Demographic information and computerized neurocognitive tests scores were exported from the online platform in which they are administered (CNS Vital Signs). Study Workbook information and patient satisfaction scores that were filled out online, were exported from the platform in which they were administered (Qualtrics). All other data was hand entered, using the double entry method. The average of the three measures for near-far convergence was used for analyses. Outcome measures from the physical activity diary and the cognitive activity diary were calculated before they were entered into the database. For the physical activity diary, the number of responses in each category was calculated. For example, category 1 corresponds to sleeping. It is likely that a participant recorded 32 "1"s (one for each 15 minute interval of the 8 hours they slept). The number for each category was then multiplied by the kcal/kg/min corresponding to that category (1=0.26, 2=0.38, 3=0.57, 4=0.69, 5=0.84, 6=1.2, 7=1.4, 8=1.5, 9=2.0).[105] The kcal/kg/min for all of the categories was summed, multiplied by the participant's body weight in kg and multiplied by 1440 (or the number of minutes in each day). This calculation provides an energy expenditure measure, which estimates the number of kcals the individual expended each day. This energy expenditure measure can then be summed across days and divided by the days to recovery for each participant, in order to calculate average physical activity per day.

For the post-schoolwork survey, the description of each cognitive activity was used to categorize that period of activity as low or high (as described in Appendix A). Classes were categorized into the following types: math, science, history, english, foreign language, art, music, physical education and technical. In order to calculate average cognitive activity per day, the length of time spent for each session of school-related cognitive activity was summed for all days from the time of the concussion until the participant was deemed recovered, and then divided by the days to recovery.

Statistical Analyses

All statistical analyses were performed in SAS (Version 9.3; SAS Institute, Inc, Cary, North Carolina). Results are considered significant at an a priori alpha level of 0.05. A summary of all outcome measures (Table 3.3) and a data summary table (Table 3.4) are provided.

Specific Aim 1: effect of group (standard-of-care vs. cognitive activity intervention) on days to recovery patient satisfaction following concussion

To address specific aim 1 regarding the effect of a cognitive activity level (cognitive activity intervention vs. standard-of-care) on days to recovery, a survival analysis using Kaplan-Meier curves with log-rank tests was conducted. All participants recovered during the observation period (no censoring). For multivariate analyses, a cox proportional hazard model, using the robust variance estimator[123] was used to examine differences in days to recovery between groups accounting for the clustering due to group assignment by school. In order to address patient satisfaction, an independent t-test was conducted.

Specific Aim 2: association between amount and intensity of school-related cognitive activity and acute change in concussion symptoms

To address specific aim 2 regarding the association between the amount and intensity of cognitive activity and acute change in concussion symptoms, general estimating equations were used. For both general estimating equations, change in symptoms was a dichotomous variable with the levels of 1) no change or decrease in symptoms, 2) increase in symptoms. For the first general estimating equation examining the influence of the amount of cognitive activity, the amount of activity was continuous (minutes of cognitive activity per session). For the second general estimating equation examining the influence of the intensity of cognitive activity, the intensity of activity has the following levels: 1) low 2) high.

Specific Aim 3: predicting days to recovery

To address specific aim 3 regarding the relationship the relationship between recovery and sex, age, history of concussion, average cognitive activity per day, average physical activity per day, symptoms at the time of injury and premorbid conditions, cox proportional hazard models were used. The cox proportional hazard models included the following predictor variables: sex (dichotomous: male and female), age (dichotomous: under 16, or 16 and older), history of concussion (dichotomous: 0 or at least 1), average cognitive activity per day from the time of injury until recovery (continuous- coded such that a one unit increase in the independent variable represented a 60 point, or one hour, increase in cognitive activity per day), average physical activity per day from the time of injury until recovery (continuous- coded such that a one unit increase in the independent variable represented a 100 point increase in energy expenditure per day), total symptom score at the time of injury (continuous- coded such that a one unit increase in the independent variable represented a 10 point increase in symptoms at the time of injury) and premorbid conditions (dichotomous: no or yes to history of any of the following- learning disability, attention deficit hyperactivity disorder, migraines, epilepsy, seizures or psychiatric conditions). The outcome variable was days to recovery.

Table 3.3 Summary of Outcome Measures

Outcome Measure	Aim	Source	Type of Variable/Operational Definition
Days to recovery	1	SCAT3, King-Devick, Near-point convergence, CNS Vital Signs	Days until participant met all of the following criteria: 1) Maintained baseline symptom score on SCAT3 ≥ 24 hours 2) Performance within 95% of baseline performance on the SCAT3, King-Devick test and near-point convergence 3) Perform within 95% of reliable change index (RCI) when comparing post-injury assessments to baseline assessments on all CNS Vital Signs domains and performance within 80% RCI on ≥ 6 of the 8 neurocognitive domains
Group	1	Group assignment	**Standard-of-care-** receive standard of care and are only given information about the amount of cognitive activity they should perform from their physician and health care providers **Intervention-** Participants receive instruction daily about the amount of cognitive activity they should participate in on a daily basis, detailing the amount of cognitive activity to be completed in one sitting, the amount of rest following each session of cognitive activity and the total amount of cognitive activity in one day
Patient satisfaction	1	Patient satisfaction survey	Continuous: total score on patient satisfaction survey
Amount of school-related cognitive activity	2	Pre and post-schoolwork surveys	Continuous: length of each session of cognitive-activity in minutes
Intensity of school-related cognitive activity	2	Post-schoolwork surveys	Dichotomous: Low, High **Low-** passive school-related cognitive activities (reading, listening to a lecture, watching a movie, etc.) **High-** active school-related cognitive activities (writing essays, taking notes, studying or taking quizzes and exams)
Sex	3	Demographic form	Dichotomous: male or female
Age	3	Demographic form	Dichotomous: 14-15, 16-18
History of concussion	3	Demographic form	Dichotomous: 0 or at least 1
Average cognitive activity per day	3	Nighttime survey Post-schoolwork survey	Continuous: sum of length of each session of school-related cognitive activity from time of injury until recovery, divided by days to recovery
Average physical activity per day	3	Nighttime survey (physical activity diary)	Sum of energy expenditure from time of injury until recovery (calculated based on Metabolic Equivalent Task associated with each 15 minute block) , divided by days to recovery

Symptoms at the time of injury	3	Time of injury SCAT3	Total SCAT3 symptom score at time of injury
Premorbid conditions	3	Demographic form	Dichotomous: yes or no; yes if history of any of the following- learning disability, attention deficit hyperactivity disorder, migraines, epilepsy, seizures or psychiatric conditions

Table 3.4 Data Summary Table

Aim		Data Source	Comparison	Method
1	To characterize the effect of cognitive activity (cognitive activity intervention vs. standard-of-care) on days to recovery and patient satisfaction.	**<u>Days to Recovery:</u>** Performance at or above baseline on all measures* **<u>Patient Satisfaction Survey:</u>** Total score	**<u>Group:</u>** 1) Intervention 2) Standard-of-care	Survival analysis using Kaplan-Meier curves with log-rank tests for days to recovery Independent t-test for patient satisfaction survey
2	To determine the association between amount and intensity of school-related cognitive activity and acute increase in concussion symptoms.	**<u>Change in symptoms:</u>** 1) No change or decrease in symptoms 2) Increase in symptoms	**<u>Amount of cognitive activity (continuous)</u>** **<u>Intensity of cognitive activity:</u>** 1) Low 2) High	Two separate general estimating equations
3	To determine the relationship between recovery and sex, age, history of concussion, cumulative cognitive activity, cumulative physical activity, symptoms at the time of injury and premorbid conditions.	**<u>Days to Recovery:</u>** performance at or above baseline on all measures*	**<u>Sex:</u>** 1) Male 2) Female **<u>Age:</u>** 1) 14-15 2) 16-18 **<u>History of concussion:</u>** <u>1) None</u> <u>2) 1+</u> **<u>Cumulative Cognitive activity (continuous)</u>** **<u>Cumulative Physical activity</u>**	Univariate cox proportional hazard models

			(continuous) **Symptoms at Time of Injury (continuous)**: Total symptoms score from SCAT3 **Premorbid Conditions:** 1) No **2)** Yes if history of any of the following- learning disability, attention deficit hyperactivity disorder, migraines, epilepsy, seizures or psychiatric conditions	

*Participant must meet the following criteria: 1) maintain baseline score on SCAT3 symptom checklist for at least 24 hours without taking any medications that were prescribed for concussion symptoms 3) performance comparable to baseline (within 95% of baseline performance) on the SCAT3, King-Devick test and near-point convergence 3) perform within 95% of reliable change index when comparing post-injury assessments to baseline assessments on all 8 neurocognitive domains, while performing within 80% of the reliable change index on at least 6 of the 8 neurocognitive domains.

CHAPTER IV

RESULTS

Overall Results

Forty participants were enrolled in the study (20 standard-of-care, 20 intervention, 27 males, 13 females, age: 15.70 ± 1.10, height: 175.26 ± 9.12 cm, weight: 69.53 ± 34.22 kg). Participant characteristics are described in Table 5.4. All of the concussions sustained by participants in this study were sport-related. Based on participant's self-reports, the majority of concussions (24/40) were caused by a head-to-head or helmet-to-helmet impact. The rest of the concussion were caused by the head making contact with another person's body (7/40), with an object (4/40), or with the ground (5/40). The majority of participants (32/40) met the criteria for being deemed recovered at their first post-injury test, which was once they had been asymptomatic compared to baseline for 24 hours. Eight participants (4 standard-of-care and 4 intervention) did not meet the criteria for recovery on their first post-injury test, but met the criteria on their second post-injury test (days between first and second post-injury test: 2.9±1.5). Change scores for performance on outcome measures are presented in Table 5.5. There were a total of 970 sessions of school-related cognitive activity among the 40 participants in this study. We were missing symptom information for 28 sessions (<3%) of cognitive activity. Therefore, 942 sessions of school-related cognitive activity were used for analyses in which change in symptom scores was an outcome. In cases in which the physical activity diary information was missing for participants (<8% of cases), the energy expenditure value from a random adjacent day was assigned.

Aim 1 Results - Effect of cognitive activity level (cognitive activity intervention vs. standard of care) on days to recovery and patient satisfaction following concussion

On univariate modeling, there was no statistically significant difference in the days to recovery between the intervention group and the standard-of-care group (Figure 5.1). Participants in the intervention group had a 34% worse chance of recovering by one-week post-injury compared to participants in the standard-of-care group. At one week post-injury, 40% of standard-of-care group had recovered, while only 20% of the intervention group had recovered (Table 5.7). There were no differences in patient satisfaction between the two groups (t_{33}=0.24, p=0.53).

Aim 2 Results - Association between amount and intensity of school-related cognitive activity and acute increase in concussion symptoms

There was no association between the amount, or intensity of a session of school-related cognitive activity and acute increase in symptoms (amount: OR=1.01, 95%CI= 0.99, 1.02, p=0.38, intensity: OR=0.96, 95%CI= 0.67, 1.39, p=0.84). Results are presented in Table 6.4.

Aim 3 Results - Influence of sex, age, history of concussion, symptoms at the time of injury, premorbid conditions, average cognitive activity and average physical activity on days to recovery

None of the variables (sex, age, history of concussion, symptoms at the time of injury, premorbid conditions, average cognitive activity or average physical activity) were significant predictors of days to recovery ($p>0.05$ for all). Hazard ratios and accompanying 95% confidence intervals and p values for the cox proportional hazard models are presented in Table 5.8.

CHAPTER V

MANUSCRIPT I

The effect of a school-related cognitive activity intervention on recovery following concussion in high school athletes

Overview

Context: Cognitive rest is suggested following concussion, yet the efficacy of limiting cognitive activity post-concussion on recovery is unclear.

Objective: To characterize the effect of a guided cognitive activity intervention (standard-of-care vs. cognitive activity intervention) on days to recovery and patient satisfaction following concussion. A secondary purpose was to determine if sex, age, concussion history, average cognitive activity per day, average physical activity per day, symptoms at the time of injury and/or premorbid conditions predict days to recovery following concussion.

Design: Cluster-randomized trial.

Setting: High school.

Patients or Other Participants: Forty high school athletes with diagnosed concussions were enrolled in the study (20 standard-of-care, 20 intervention; 27 males, 13 females; age: 15.7 ± 1.1 yrs; height: 175.3 ± 9.1 cm; weight: 69.5 ± 34.2 kg).

Interventions: Participants from four high schools were administered baseline testing on measures of concussion symptoms, neurocognition, postural control and vision. Initially, two schools were randomly assigned to the standard-of-care group and two schools were assigned to the intervention group. After the minimum number of participants for the standard-of-care group was attained, the standard-of-care schools were converted to intervention schools. All participants recorded their physical and cognitive activity from the time of injury until they were deemed recovered. Intervention group participants received guidance on how much school-related cognitive activity to complete on a daily basis, while the standard-of-care group followed instructions given to them by their healthcare providers.

Main Outcome Measures: Days to recovery, patient satisfaction, sex, age, history of concussion, average cognitive activity per day, average physical activity per day, symptoms at the time of injury and premorbid conditions.

Results: There were no statistically significant differences in days to recovery (standard of care: 9.1 ± 4.4, intervention: 11.5 ± 5.0; p=0.12) or patient satisfaction (t_{33}=0.24, p=0.53) between the standard-of-care and intervention group. None of the following variables were predictors of recovery: sex, age, previous history of concussion, average cognitive activity per day, average physical activity per day, symptoms at the time of injury or premorbid conditions (p>0.05 for all).

Conclusions: Although cognitive rest is widely recommended following concussion, this study did not provide evidence of a benefit from a gradual return to school-related cognitive activity intervention. Individuals in the standard-of-care group tended to recover faster than individuals in the intervention group.

Key Words: cognitive rest, TBI, academic accommodations

Introduction

Concussions, one of the most common forms of traumatic brain injury, are defined as a "complex pathophysiological process affecting the brain, induced by biomechanical forces"[2] that often result in a series of symptoms, neurocognitive deficits and balance deficits. There are several factors believed to affect susceptibility to, and recovery from sport-related concussion, including age, sex, previous concussion history, psychiatric conditions, learning disabilities, mood disorders, and migraines.[124] Younger athletes are considered more susceptible to concussion, and often experience a longer recovery period, making concussions of particular concern for youth and adolescents.[5-9] These more severe consequences in younger athletes are attributed to their brains having not yet fully developed.[10] Therefore, it is especially important to implement effective strategies for the management of concussion in youth athletes.

Current management of sport-related concussion is focused on both physical and cognitive rest, until concussion symptoms resolve. Published evidence evaluating the effect of rest following a concussion is sparse. There are few specific recommendations for cognitive rest. Instead, clinicians are instructed to take a "sensible approach that involves a gradual return to school and social activities."[2] Academic accommodations, such as rest breaks or extra time for assignments and tests, are suggested following concussion, because signs and symptoms of concussion can make participating in school very difficult.[11] Symptoms such as feeling in a "fog" and difficulty concentrating or remembering can have negative consequences in an academic setting because school requires concentration and working memory, placing extra neurometabolic demands on a healing brain.[12] Upon returning to school, seventy percent of students recovering from a concussion reported needing some form of support (e.g. more rest breaks, or extended time on assignments) according to their parents.[12] Thirty-eight percent of those same parents worried that their child's grades had been or would be affected by the concussion.[12] The stress associated with returning to normal functional activities before the patient is ready to do so, may lead to the development of post-concussion complaints and reappearance or worsening of symptoms.[13] While academic accommodations are thought to be effective, little is known about the proper amount and type of cognitive rest that should be recommended throughout various stages of the recovery process.

There is some evidence that individuals with higher levels of cognitive activity post-concussion experience longer times to symptom resolution.[111] Conversely, there is a growing body of evidence that receiving or following recommendations for cognitive rest results in no difference in recovery time, and may actually result in longer recovery time.[14,15] In adolescent athletes, adherence to treatment recommendations, including physical rest, cognitive rest with restrictions from electronics, and cognitive rest with restrictions from school, was not a significant predictor of the number of days of treatment. In fact, high levels of adherence to rest resulted in an increased average number of days of treatment, while those who reported being less adherent recovered faster (not statistically significant).[14] In another sample of 184 athletes aged 8-26, the recommendation for cognitive rest was not significantly associated with time to concussion symptom resolution.[15] Of the 63% of patients who received recommendations for cognitive rest, 59% experienced prolonged symptoms.[15] A prospective study examining the role of various levels of physical and cognitive activity in the recovery process following concussion is necessary to establish and implement evidence based management protocols. Therefore, the purpose of this study was to characterize the effect of a guided cognitive activity intervention (cognitive activity intervention vs. standard-of-care) on days to recovery and patient satisfaction following concussion. A secondary purpose was to determine if sex, age, concussion history, average cognitive per day, average physical activity per day, symptoms at the time of injury and modifiers of concussion predict days to recovery following concussion.

Methods

Instrumentation

Demographic Information

Demographic information for all participants was collected during baseline testing, as part of a paper or online survey. Information collected included age, sex, height, weight, academic year, and self- reported history of learning disability, attention deficit hyperactivity disorder, migraines, epilepsy, seizures or psychiatric conditions.

Sport Concussion Assessment Tool 3 (SCAT3)

The SCAT3 was administered during baseline and during post-injury assessments. The SCAT3 includes a symptom scale, basic neurological examination, a mental status examination (the Standardized Assessment of Concussion) and a balance function assessment (a modified version of the Balance Error Scoring System or a tandem gait task). It is designed to be a sideline tool for the assessment of concussion and each of the individual components may be interpreted independently to aid in concussion evaluation.[26] Outcome measures for the SCAT3 include a symptom score, a Standardized Assessment of Concussion (SAC) total score, Balance Error Scoring System (BESS) total score, and tandem gait score. The symptom scale asks the participants to score themselves on 22 concussion symptoms based on how they feel at the time of evaluation. The scale includes: 0 (none), 1 and 2 (mild), 3 and 4 (moderate) and 5 and 6 (severe). This allows for a total number of symptoms ranging from 0-22 and a total symptom score, taking severity into account, ranging from 0-132. The Standardized Assessment of Concussion (SAC) is a mental status examination. It includes five components: orientation, immediate memory, concentration and delayed recall. There are a total of 30 possible points on the SAC. A modified version of the Balance Error Scoring System (BESS) is included in the SCAT3, with the option of completing the full version BESS. The modified version of the BESS only includes the firm stance conditions, while the full version of the BESS includes both the firm stance conditions and the foam stance conditions. For this study, the full version of the BESS was used. The BESS involves three different stances (double leg, single leg and tandem stance), which are completed twice (once on a firm surface and once on an unstable or foam surface), for a total of six twenty second trials.[65] The test takes about five minutes to administer, and errors are recorded for each 20 second trial. Errors include lifting hands off iliac crests, opening eyes, stepping, stumbling or falling, moving the hip into greater than thirty degrees of flexion or abduction, forefoot or heel losing contact with the ground or remaining out of the testing position for more than five seconds.[67] Errors are summed for firm stance trials, foam stance trials, and total of all six trials. The BESS has been found to be both valid and reliable.[68,69]

Computerized Neurocognitive Assessment- CNS Vital Signs

CNS Vital Signs (CNS Vital Signs, LLC, Chapel Hill, NC) consists of a series of computerized neurocognitive tests. One of the purposes of CNSVS is to detect changes in neurocognitive performance over time, allowing for assistance in the evaluation of concussion. CNSVS was administered during baseline testing and post-injury assessments. During all assessments, participants were administered CNSVS in a controlled environment and were given standardized instructions. CNSVS assesses a multitude of cognitive domains, using a series of individual subtests, which are described in detail by Gualtieri and Johnson.[58] Main outcome measures include the standard scores for the following clinically relevant domains: Verbal Memory, Visual Memory, Psychomotor Speed, Cognitive Flexibility, Complex Attention, Processing Speed, Reaction Time, and Executive Functioning. The standard scores place all outcomes on the same scale and provide for an easier clinical understanding. The standard scores are based on a normative dataset that matches participants by age. A standard score of less than 70 is considered a score that indicates a likely deficit or impairment, 70-79 represents a possible moderate deficit and impairment, 80-90 represents a slight deficit and impairment, 91-110 represents normal function and normal capacity, and greater than 100 represents high function and high capacity.

Visual Assessments

Saccades. The King-Devick test is a reading efficiency test for sideline diagnosis of sport concussion. The King-Devick test provides a rapid assessment of cognitive visual processing and performance.[73] During the King-Devick test, participants were asked to rapidly read single-digit numbers from a series of three cards, progressing in difficulty. Participants were asked to read the numbers from left to right and top to bottom as quickly as possibly, without making any errors. The participants were given a practice card before the test cards, to ensure that they understood the directions. The test administrator followed along on the King-Devick scorecards in order to record any errors that the participants make during the test. The King-Devick test has been shown to be valid, reliable and useful in the detection of concussion.[73]

Vergence. Near-point convergence is another quick and easy to administer visual assessment. To determine near point of convergence, the participant was asked to track a high-acuity visual stimulus slowly moving inward along the midline of vision. When the patient reports diplopia or the test administrator notices a break in the fusion of the eyes, the distance of the stimulus from the face was recorded and noted as the near point of convergence.[74] The participants completed the assessment three times and the average of the three assessments were used for data analysis.

Intervention

The cognitive activity intervention involved scaling the amount of cognitive activity that the individual participates in on a daily basis. The intervention includes five stages (Table 5.1). Each stage recommends a certain environment (home or at school), the amount of school-related cognitive activity to be completed in one sitting, the amount of rest he or she should take after each session of cognitive activity and the total amount of cognitive activity he or she should complete in one day. This intervention was based upon the recommendations of Master et al.,[125] which suggests starting with homework at home before school work at school, and starting with 20-30 minute increments, before progressing to a part day at school and finally a full day at school. In our intervention, stage one was to be completed at home and included a maximum of 20 minutes of cognitive activity at a time, followed by a 30 minute break, with a total of no more than 1 hour of cognitive activity during the day. A session was defined as a sustained period of school-related cognitive activity (i.e. a class or homework) during which work for a single class was completed. If the participant experienced any increase in symptoms while completing cognitive activity, he or she was instructed to stop their activity at that time. Once the participant's symptoms returned to their pre-cognitive activity level, he or she was instructed to take the suggested rest break before beginning any more cognitive activity. Once participants were able to complete the maximum recommended amount of cognitive activity in a given day without any of their sessions of cognitive activity resulting in an overall increase in symptoms greater than six or any one symptom increasing greater than three points, then he or she could progress to the next stage of the intervention. Participants were also given specific recommendations according to the symptoms they were experiencing, based on recommendations of Halstead et al.,[120] which are described in Table 5.2.

Study Workbook

All participants were asked to complete a Study Workbook every day following their concussion until they were deemed recovered. Participants were given the opportunity to complete the Study Workbook on a series of paper surveys, online using Qualtrics surveys, or through a combination of paper and online surveys. A variety of methods were available to the participants in order to lessen the burden to participants and to increase compliance. The Study Workbook was used to collect information about participants' school-related cognitive activity. Prior to each session of school-related cognitive activity, participants were asked to complete an abbreviated symptom checklist. The abbreviated symptom checklist asked participants to rate their symptoms on a scale of 0-10 (symptoms: headache, fatigue, concentration problems, irritability, fogginess and sensitivity to light or noise). Participants were then asked to complete the abbreviated symptoms checklist immediately after concluding each session of cognitive activity. They were also asked how long each session of cognitive activity lasted, whether the activity was completed at home or at school, what class the session of cognitive activity was related to (e.g. math, science, or history), what tasks they completed (e.g. reading, studying, listening to a lecture, taking notes, doing group work), and whether completing each task was more difficult that usual.

Participants were asked to complete the nighttime survey at the end of the day, as close to when they were trying to fall asleep as possible. The nighttime survey took about 5-10 minutes to complete and consisted of an abbreviated symptom checklist, the 22-item symptom scale from the SCAT3, and a physical activity diary. The physical activity diary was completed once at the end of each day, which has been shown to be a valid and reliable means of reporting in a high school population.[104] The activity diary takes both the amount and intensity of activity into account, allowing for a calculation of energy expenditure. Each activity that the participants performed on a daily basis was assigned an energy cost, in METS, from previous studies.[20] This allowed for a calculation of energy expenditure per day, controlling for the participant's body weight (kJ/d).

<u>Patient Satisfaction Survey</u>

The participant was asked to complete the patient satisfaction survey two weeks after they were deemed recovered. The patient satisfaction survey is adapted from the

Patient Satisfaction Questionnaire (PSQ-18), which is a publically available scale that measures general patient satisfaction with care. The PSQ-18 was designed based on feedback from patients using input from providers about the care they receive and has been used in various settings.[121,122] The PSQ-18 yields separate scores for each of seven different subscales: general satisfaction, technical quality, interpersonal manner, communication, financial aspects, time spent with doctor, accessibility and convenience. The questions examining the subscales relevant to this study (general satisfaction, technical quality, communication and time spent with doctor) were maintained in the patient satisfaction survey. Questions examining subscales that are not relevant to this study (interpersonal manner, financial aspects, accessibility and convenience) were replaced with questions examining support during the process of returning to school and sports following concussion. Some PSQ-18 items are worded so that agreement reflects satisfaction with medical care, whereas other items are worded so that agreement reflects dissatisfaction with medical care. All items were scored so that high scores reflect satisfaction with medical care.

Participants and Procedures

Procedures are described in Figure 5.1. Athletes (n=304) from the following sports were baseline tested prior to participation in sport: football, soccer, field hockey, volleyball, basketball, wrestling, lacrosse, baseball, softball and cheerleading. Of these high school athletes, forty were diagnosed with a sport-related concussion at one of four high schools over the course of the 2014-2015 academic year and were included in the study. Institutional Review Board approved informed consent documents were delivered to high school players and their parents/legal custodians at baseline testing.

Prior to the beginning of the 2014-2015 academic year, two of the four high schools were assigned to the intervention group, and the other two schools were assigned to the standard-of-care group. Two researchers were present for the randomization. Researchers listed the schools in the order in which they were scheduled to be baseline tested. The researchers then assigned one side of a coin to the standard-of-care group and the other side of the coin to the intervention group. The researchers then flipped the coin to determine group assignment for each school based in the order for which they were listed. The first two coin flips indicated assignment to the standard-of-care group, so the second two schools were assigned to the intervention group. Prior to the start of the season, athletes at each of the four high schools completed baseline testing administered by his or her athletic trainer and a clinical outreach team. Participants were assessed on a clinical measure of concussion (Sport Concussion Assessment Tool 3, or SCAT3), tests of visual vergence and saccades (the King-Devick test and near-point convergence) and a computerized neurocognitive test (CNS Vital Signs), which provided a baseline score on the selected variables. Athletes also completed a demographic information survey.

Concussed athletes who participated in the study had an initial meeting with a member of the research team following their concussion, either in person or over the phone, within 24 hours of their injury. During the initial meeting, all participants were given the "Study Workbook," which allowed them to keep track of their symptoms, physical activity and cognitive activity over the next several days to several weeks. The standard-of-care group simply followed instructions given to them by their physician or athletic trainer and were not given any information about how much activity to complete by members of the research team. Concussed participants in the intervention group received the gradual return to cognitive activity intervention, detailing how much school-related cognitive activity he or she should complete on a daily basis.

All participants, regardless of group, talked to a member of the research team on a daily basis, either in person or over the phone. These “daily check-ins” were conducted to ensure that the Study Workbooks were being completed properly by the participants, and for identifying when the participant was symptom free (compared to baseline SCAT3 symptom scores). Once participants had been symptom free for 24 hours, they were administered a post-injury assessment, during which they were reassessed on baseline measures (SCAT3, the King-Devick test, near-point convergence and CNS Vital Signs) to determine whether or not they had reached recovery.

Days to recovery was defined as number of days from the time of injury until the participant met all of the following conditions: maintained baseline score on SCAT3 symptom score for at least 24 hours without taking any medications that were prescribed for concussion symptoms, performance comparable to baseline (at or above 95% of baseline performance) on the remaining components of SCAT3, King-Devick test and near-point convergence and performance within the 95% reliable change index when comparing post-injury assessments to baseline assessments on all 8 neurocognitive domains, while performing within the 80% reliable change index (clinically more conservative) on at least 6 of the 8 neurocognitive domains.[126] If a participant did not meet the criteria for recovery at their post-injury assessment, the participant’s physician determined the timeline for follow-up assessments after the initial post-injury assessment based on the participant’s clinical presentation. Once participants were deemed recovered, they were no longer asked to record their symptoms, physical activity or cognitive activity. They proceeded with activity and a gradual return to sport, under the direction of their physician and athletic trainer. Two weeks after the participants were deemed recovered, they were asked to complete a short, 18 question patient satisfaction questionnaire. After completion of the patient satisfaction survey, the participant continued to be monitored for re-injury, but otherwise their participation in the study was concluded.

Compliance

All participants were required to complete at least 80% of the study workbook in order to participate in the study. Participants in the intervention group were required to remain compliant with the school-related cognitive activity restrictions placed on them for at least 80% of the days from their time of injury until they were deemed recovered in order to participate in the study.

Data Reduction

Data entry and reduction methods are presented in Table 5.3.

Statistical Analyses

All statistical analyses were performed in SAS (Version 9.3; SAS Institute, Inc, Cary, North Carolina). To address our primary aim regarding the effect of cognitive activity level (cognitive activity intervention vs. standard-of-care) on days to recovery, a survival analysis using Kaplan-Meier curves with log-rank tests was conducted. The outcome of interest was number of days until recovery. All participants recovered during the observation period (no censoring). The independent variable was group (cognitive activity intervention and standard-of-care). Effect size measures (Cohen's *d*) were also determined to indicate the standardized difference between the two groups in days to recovery, and Cohen's guidelines [127] for interpreting Cohen's *d*'s (small effect, $d = 0.2$; medium effect, $d = 0.5$; large effect, $d = 0.8$) were followed. In order to establish whether there were differences between the two groups that could influence findings, we conducted a chi-square analysis to determine the association between group and sex, age, concussion history, and history of premorbid conditions, and an independent t-test to determine differences between the two groups on SCAT3 total symptom score from the time of injury.

For multivariate analyses of our secondary aim, a cox proportional hazard model using the robust variance estimator[123] was used to examine differences in days to recovery between groups accounting for the clustering due to group assignment by school. The cox proportional hazard models included the following predictor variables: sex (dichotomous: male and female), age (dichotomous: under 16, or 16 and older), history of concussion (dichotomous: 0 or at least 1), average cognitive activity per day from the time of injury until recovery (continuous- coded such that a one unit increase in the independent variable represented a 60 point, or one hour, increase in cognitive activity per day), average physical activity per day from the time of injury until recovery (continuous- coded such that a one unit increase in the independent variable represented a 100 point increase in energy expenditure per day), total symptom score at the time of injury (continuous- coded such that a one unit increase in the independent variable represented a 10 point increase in symptoms at the time of injury) and premorbid conditions (dichotomous: no or yes to history of any of the following- learning disability, attention deficit hyperactivity disorder, migraines, epilepsy, seizures or psychiatric conditions). The outcome variable was days to recovery. Hazard ratios and accompanying 95% confidence intervals were estimated using the model. In order to address patient satisfaction, an independent t-test was conducted. The independent variable was group (cognitive activity intervention and standard-of-care) and the dependent variable was patient satisfaction survey total score.

Results

All of the concussions sustained by participants in this study were sport-related (Table 5.4). The majority of concussions (24/40) were caused by a head-to-head or helmet-to-helmet impact. The rest of the concussions were caused by the head making contact with another person's body (7/40), with an object (4/40) or with the ground (5/40). The majority of participants (32/40) met the criteria for being deemed recovered at their first post-injury test, which was administered once they had been asymptomatic compared to baseline for 24 hours. Eight participants (4 standard-of-care and 4 intervention) did not meet the criteria for recovery on their first post-injury test, but met the criteria on their second post-injury test (days between first and second post-injury test: 2.88±1.46). Change scores for performance on outcome measures are presented in Table 5.5.

All participants completed at least 80% of their study workbooks during their recovery period, and all participants in the intervention group reported being compliant with school-related cognitive activity restrictions on 80% of their days until recovery. None of the participants in the intervention group were 100% compliant with school-related cognitive activity restrictions, most often due to lack of compliance during Stage

1. Regardless of group, participants did not complete cognitive activity every day following concussion, because participants did not always have schoolwork to do on weekends or days off of school. Table 5.6 demonstrates how much cognitive activity participants completed for each day that they actually completed cognitive activity following their concussion, compared to the recommended amount for the cognitive activity group, if they progressed through one stage each day. For example, if a participant sustained a concussion on a Thursday, and went to school on Friday, but then did not complete any more schoolwork until returning to school on Monday, then the "First Day" of cognitive activity represents his first day post-injury, while the "Second Day" of cognitive activity represents his fourth day post-injury. We were missing physical activity diary information in <8% of cases. In cases in which the physical activity diary information was missing for participants, the energy expenditure value from a random adjacent day was assigned. We were missing school-work surveys in <3% of cases. If participants forgot to complete the school-work survey on a given day, the amount of activity they had completed that day was retrospectively collected (within 24 hours), and used to calculate average cognitive activity per day.

In univariate modeling, there was no difference in the days to recovery between the intervention group and the standard-of-care group (Figure 5.2). At one week post-injury, 40% of standard-of-care group had recovered, while only 20% of the intervention group had recovered (Table 5.7). The effect size for differences in days to recovery between the two groups was moderate (d=0.50). We were missing patient satisfaction surveys for 6 participants; therefore only 34 surveys were included in analyses. There were no differences in patient satisfaction between the two groups (t_{33}=0.24, p=0.53).

There were no differences between the groups on age (X^2=1.94, p=0.75), concussion history (X^2=2.13, p=0.14), history of premorbid conditions (X^2=0.78, p=0.38) or SCAT3 total symptom score at the time of injury (t_{39}=-1.74, p=0.09). There was an association between sex and group, with more females in the intervention group compared to the standard-of-care group (X^2=9.23, p=0.002). Hazard ratios and accompanying 95% confidence intervals and p values for the cox proportional hazard models are presented in Table 5.8.

Discussion

The findings of this study are consistent with previous literature demonstrating that recommending cognitive activity restrictions does not promote recovery, and may in fact delay recovery.[14,15,128] There are several possible explanations for this finding. For one, while our participants were compliant with our recommendation on at least 80% of the days throughout their recovery, no one was 100% compliant with our recommendations. The majority of our participants in the intervention group exceeded their recommended amount of cognitive activity during stage one of the intervention, which recommended that participants complete no more than one hour of school-related cognitive activity throughout the day. Future studies should collect qualitative information about what prevents participants from remaining adherent to school-related cognitive activity restrictions. Additionally, the intervention in this study primarily focused on limiting the amount of school-related cognitive activity that individuals completed on a daily basis. The intervention did not recommend limiting certain types of activities, such as taking notes, writing short answers or essays or translating a foreign language. It is possible that the type of cognitive activity that individuals complete post-concussion may be more important than the amount of cognitive activity. Future research should examine the influence of the type or intensity of cognitive activity and how it influences recovery following concussion.

An alternative explanation for our findings is that withholding an individual from returning to school can cause increased stress and anxiety, which can delay recovery.[13] Currently, this explanation is a theory, because we did not measure stress or anxiety in this study. However, this theory has been cited in other literature examining recovery following head injury. In this study, participants in the intervention group typically spent a longer time out of school, which separated them from their normal routines, friends and teammates, which can lead to anxiety and isolation.[15] Additionally, increased anxiety can develop as students began to accumulate schoolwork by continuing to take time off of school. Furthermore, it is possible that since the intervention group was effectively being reminded on a daily basis that school and school work could make their symptoms worse, they were more likely to be aware of their symptoms. Thomas et al. [128] also reported that patients who were prescribed strict rest reported more daily postconcussive symptoms, which may have been due to a reporting bias. We did not observe any differences in patient satisfaction, likely because the satisfaction of decreased recovery time in the standard-of-care group outweighed any potential increase in patient satisfaction resulting from the intervention. It is also possible that participants in the intervention group were frustrated because they were being told they could not return to school as quickly as they would have liked to return, and because their social support had been removed. Another potential explanation for the lack of differences in days to recovery and patient satisfaction between the two groups is that physicians caring for patients in the standard-of-care group provided them with similar recommendations we provided to the intervention group. Unfortunately, we did not collect information about what instructions were given to individuals in the standard-of-care group, which is a limitation of this study. The goal of our intervention was to aid participants in gradually returning to school, and promoting recovery, but the intervention was not effective in promoting recovery or improving patient satisfaction with care.

While cognitive rest is suggested following concussion, there is limited evidence supporting cognitive rest. Our findings are consistent with previous findings that recommending strict rest following mild traumatic brain injury offered no benefit over current usual care.[128] It is also consistent with theories that adolescents' concussion symptom reporting may be influenced by restricting activity. [128] These findings suggest that clinicians should consider initially explaining the potential benefits of cognitive rest to their patients and instructing them to complete the schoolwork that they feel they are able to complete. Our data suggest conservative recommendations, such as prolonged absences from school following concussion, should be approached cautiously. In fact, returning to school, even if the patient is not able to fully engage in coursework may be beneficial from a social and psychological standpoint.[14]

Other factors may have an effect on recovery following concussion, such as sex, age and previous history of concussion. However, evidence supporting the influence of these factors and recovery is conflicting. There were more females in our intervention group than our standard-of-care group. However, in our entire sample, none of the following variables predicted days to recovery: sex, age, previous history of concussion, premorbid conditions, symptoms at the time of injury, average cognitive activity per day and average physical activity per day. For participants in the standard-of-care group, the average minutes of cognitive activity per day predicted days to recovery, such that on average, for each additional hour of cognitive activity completed per day, participants in the standard-of-care group were 1.45x more likely to recover at any given time point. It is likely that this effect was not seen in the intervention group, because the intervention group was given a regimented amount of cognitive activity to complete each day. Again, this finding suggests that more cognitive activity following concussion may actually beneficial to healing. While not statistically significant, sex, age and premorbid conditions may have a small effect on recovery. On average, the probability of recovering at any given time point was 31% lower in females than males, 10% lower in individuals under 16 years of age than 16 or older, and 42% lower in individuals with a premorbid condition than those without a premorbid condition in our sample. These factors should continue to be analyzed in future research, because this study had a relatively small sample size with large confidence intervals. Previous literature indicates that age, sex, psychiatric conditions, learning disabilities, mood disorders, and migraines can affect recovering following concussion.[124] Surprisingly there was no difference in days to recovery between participants who had a history of concussion and those who did not. Previous research has demonstrated an association between prior concussions and longer recovery times in college football players,[25] but no difference in protracted recovery based on concussion history in high school football players. [129] It is possible that age modifies the role of concussion history on recovery. The number of previous concussions could also modify the role of concussion history on recovery. In our sample, we only had 3 participants who reported a history of 2 previous concussions. All other participants reported a history of 0 or 1 previous concussion. The magnitude of the influence of a previous concussion is likely greater when individuals report a history of 2 or more previous concussions.[123] Larger scale studies should continue to explore these relationships, as they may guide treatment following concussion.

Our findings must be interpreted in light of several limitations. We are relying on self-report measures of symptoms, cognitive activity and physical activity. We assume that participants were honest and truthful in their reporting of symptoms and the amount of cognitive and physical activity they were completing. We did not record what instructions were given to participants in the standard-of-care group; therefore, they could have been given similar instructions as the intervention group. We also may have had insufficient power to address some of our aims. These findings should be interpreted as preliminary, and future research should continue to explore factors affecting recover following concussion.

In our study, a gradual return to school-related cognitive activity intervention did not provide evidence of a benefit. Cognitive rest is suggested following concussion, but strict cognitive rest should be viewed cautiously. Patients should be given information about academic accommodations and strategies for returning to school following concussion, but should be allowed to progress at a pace that is comfortable for them. Other factors such as sex, age, and premorbid conditions should also be taken into account when developing a treatment plan. Although cognitive rest is widely recommended, it may not be beneficial for recovery following concussion. Future research should include multi-center prospective cohort studies with multiple levels of physical and cognitive activity restrictions.

Figure 5.1 Study Procedures

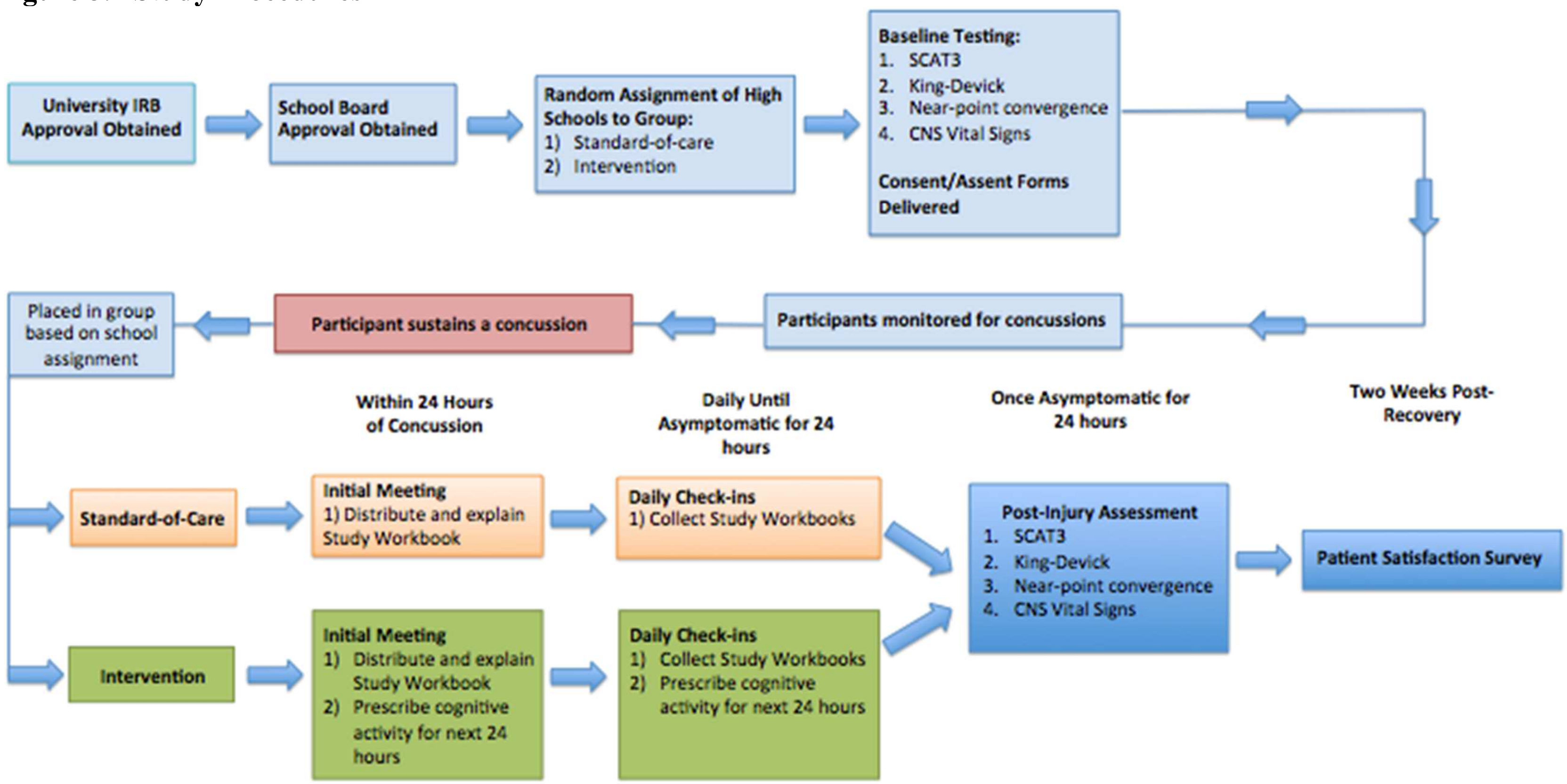


Table 5.1. Stages of School-Related Cognitive Activity Intervention

Stage	Environment	Only complete this much cognitive activity in one sitting (session):	Rest for at least this long following each session of cognitive activity:	Complete no more than a total of this much cognitive activity each day:
1	Home	20 minutes	30 minutes	1 hour
2	Home	45 minutes	20 minutes	3 hours
3	School	2 hours	10 minutes	5 hours
4	School	4 hours	10 minutes	7 hours
5	School	8 hours	--	--

Table 5.2 Recommendations Based on Halstead et al.[120] used in intervention

Symptom	Recommendations
Headache	• Take frequent breaks throughout the day • Rest in a quiet room if symptoms increase
Dizziness	• Leave each class early in order to allow extra time to get to the next class
Visual symptoms (i.e. blurred vision)	• Reduce the brightness on computer or phone screens • Wear sunglasses if necessary • Avoid fluorescent lights
Noise sensitivity	• Eat lunch in a quiet area with a classmate • Use earplugs if needed
Difficulty concentrating or remembering	• Postpone all exams
Sleep disturbance	• Late start to day to catch up on sleep

Table 5.3 Data Entry and Reduction

Source	Data Entry Method
Demographic information and computerized cognitive testing scores	Scores exported directly from the online platform in which they were administered (CNS Vital Signs)
Study Workbooks and patient satisfaction surveys (completed online)	Scores exported directly from Qualtrics
All other data	Hand entered using double entry method: two researchers independently entered data into the same template data sheet; mathematical subtractions were used to determine error rate (<0.01%) and were corrected upon visual inspection for accuracy.
Source	**Data Reduction Method**
School-work Surveys	**Average cognitive activity per day**: Sum of the length of time spent for each session of cognitive activity for each participant, divided by the number of days from their injury until they were deemed recovered. If participants forgot to complete the school-work survey on a given day, the length of their sessions of cognitive activity they had completed that day was retrospectively collected (within 24 hours), and used to calculate average cognitive activity per day.
Physical Activity Diary	**Average physical activity per day:** Sum of energy expenditure for all days from time or injury until participant was deemed recovered, divided by days to recovery. **Energy expenditure (kcal) per day-** Sum of number of responses for each category, multiplied by the kcal/kg/min corresponding to that category (1=0.26, 2=0.38, 3=0.57, 4=0.69, 5=0.84, 6=1.2, 7=1.4, 8=1.5, 9=2.0)[105], summed across all categories, multiplied by the participant's body weight in kg and multiplied by 1440 (or the number of minutes in each day). If information for a given day was missing, the energy expenditure from a random adjacent day was assigned to the missing day.

Table 5.4 Demographic Information for Participants and Injury Characteristics

Variable	Overall	Standard-of-Care	Intervention
Age (years)	15.7 ± 1.1	15.7 ± 1.1	15.7 ± 1.1
Height (cm)	175.3 ± 9.1	177.8 ± 7.2	170.2 ± 9.5
Weight (kg)	69.5 ± 34.2	73.5 ± 38.4	66.2 ± 29.5
Sex			
Males	27	18	11
Females	13	2	9
Previous Concussions			
0	30	13	17
1	7	6	1
2	3	1	2
Modifiers			
Learning Disability	1	1	0
ADHD	6	4	2
Psychiatric condition	0	0	0
Migraine	0	0	0
Mechanism of Injury			
Sport-Related			
Girl's Basketball	4	0	4
Boy's Basketball	0	0	0
Cheerleading	1	1	0
Field Hockey	1	0	1
Football	16	11	5
Girl's Lacrosse	1	0	0
Boy's Lacrosse	5	2	3
Girl's Soccer	2	2	2
Boy's Soccer	6	1	4
Volleyball	1	0	1
Wrestling	3	3	0

Table 5.5 Change scores (post injury score that met recovery criteria – baseline score) on outcome measures used to determine recovery overall and by group

Outcome Measures	Overall Mean ± SD	Standard-of-Care Mean ± SD	Intervention Mean ± SD
Standardized Assessment of Concussion	1.38±2.77	0.95±1.99	1.84±3.40
Balance Error Scoring System*	-4.36±4.59	-4.45±4.87	-4.26±4.39
Tandem Gait (sec)*	-1.23±2.87	-0.74±3.25	-1.75±2.39
King-Devick (sec)*	1.06±14.10	2.42±16.99	-0.38±10.53
Near-point Convergence (cm)*	-0.26±2.51	-0.94±2.46	0.49±2.54
CNS Vital Signs (Standard Scores)			
Verbal Memory	7.79±23.02	0.05±18.09	15.94±25.22
Visual Memory	-1.38±15.25	-2.75±15.14	0.05±15.64
Psychomotor Speed	7.95±18.13	4.10±10.41	12.00±23.36
Reaction Time	3.87±11.80	6.15±14.56	1.47±7.66
Complex Attention	10.53±23.81	11.00±28.86	10.05±17.82
Cognitive Flexibility	11.33±15.24	11.60±17.63	11.05±12.73
Processing Speed	9.46±11.14	9.65±10.52	9.26±12.05
Executive Functioning	11.13±14.07	11.90±16.10	10.32±11.94

*Negative change score indicates improvement on the test from baseline to post-injury

Table 5.6 Total Amount of Cognitive Activity per Day of Participating in Cognitive Activity (first five days of cognitive activity only)

Group	Days Until First Session of Cognitive Activity (Mean ± SD)	Total Days of Cognitive Activity (Mean ± SD)	Total Amount of Cognitive Activity per Day of Cognitive Activity in minutes (Mean ±SD; Range)				
			First Day	Second Day	Third Day	Fourth Day	Fifth Day
Recommended (Intervention Only)	--	--	60	180	300	420	480
Intervention	4.1 ± 2.7	6.0 ± 2.4	182.0 ± 100.0; 40-360	206.5 ± 83.9; 85-360	269.5 ± 130.3; 90-735	239.4 ± 89.9; 25-360	269.6 ± 79.1; 150-360
Standard-of-Care	2.5 ± 1.4	8.6 ± 3.9	279.3 ± 114.6; 30-525	315.5 ± 90.5; 120-440	343.1 ± 181.2; 10-728	322.5 ± 159.8; 90-620	295.8 ± 74.4; 150-375

Table 5.7 Percent recovered overall and by group at one week intervals from the time of injury

Group	Days to Recovery Mean ± SD	Percent Recovered			
		One Week (Day 7)	Two Weeks (Day 14)	Three Weeks (Day 21)	Four Weeks (Day 28)
Overall	10.28 ± 4.81	30 (12/40)	85 (34/40)	95 (38/40)	100 (40/40)
Standard of Care	9.10 ± 4.38	40 (8/20)	90 (18/20)	100 (20/20)	100 (20/20)
Intervention	11.45 ± 5.04	20 (4/20)	80 (16/20)	90 (18/20)	100 (20/20)

Figure 5.2 Kaplan Meier Curve of Days to Recovery

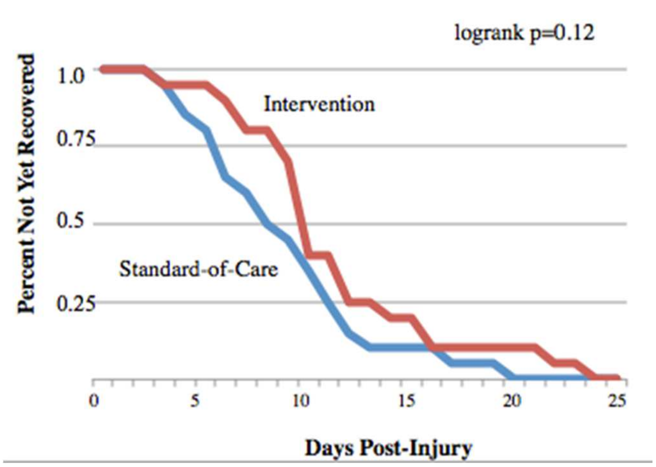


Table 5.8 Univariate hazard ratios showing associations with days to recovery

Variable		n	Days to Recovery (Mean ± SD)	Overall		Standard-of-Care		Intervention	
				Hazard Ratio (95% CI)	P value	Hazard Ratio (95% CI)	P value	Hazard Ratio (95% CI)	P value
Sex	**Male**	27	9.70 ± 4.69	0.69 (0.35, 1.37)	p= 0.29	0.76 (0.18, 3.51)	p= 0.76	0.79 (0.31, 2.02)	p= 0.62
	Female	13	11.46 ± 5.03	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Age	**14-16**	17	10.24 ± 4.07	0.90 (0.47, 1.73)	p=0.76	1.69 (0.67, 4.26)	p=0.27	0.59 (0.23, 1.55)	p=0.29
	16-18	23	10.30 ± 5.38	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Previous Concussions	**0**	30	10.36 ± 4.72	1.03 (0.50, 2.13)	p= 0.94	0.79 (0.30, 2.11)	p= 0.64	0.94 (0.27, 3.36)	p= 0.93
	1+	10	10.00 ± 5.33	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Premorbid Conditions	**No**	33	9.74 ± 4.40	0.58 (0.23, 1.40)	p=0.22	0.45 (0.13, 1.55)	p=0.20	0.55 (0.12, 2.50)	p=0.39
	Yes	7	13.33 ± 6.28	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Day of Injury Symptoms (per 10 point increase)	**20-30**		10.88 ± 3.31	0.86 (0.73, 1.01)	p= 0.05	0.82 (0.65, 1.04)	p= 0.10	0.91 (0.73, 1.13)	p= 0.39
	30-40		8.88 ± 4.05	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Average minutes of cognitive activity per day (per hour increase)	**1-2 hr**		11.46 ± 4.75	1.27 (0.97, 1.64)	p=0.08	1.45 (1.06, 1.96)	p=0.02*	0.83 (0.48, 1.44)	p=0.51
	2-3 hr		9.86 ± 3.35	1.00 (ref)		1.00 (ref)		1.00 (ref)	
Average physical activity per day (per 100 increase in energy expenditure)	**2800**		10.67 ± 6.51	1.02 (0.96, 1.09)	p=0.54	1.03 (0.94, 1.12)	p=0.05	0.99 (0.89, 1.11)	p=0.89
	2900		13.00 ± 9.85	1.00 (ref)		1.00 (ref)		1.00 (ref)	

*Statistically significant at the 0.05 alpha level

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CHAPTER VI

MANUSCRIPT II

The effect of amount and intensity of school-related cognitive activity on change in symptoms and difficulty in task completion following concussion

Overview

Context: Cognitive rest is suggested as a treatment for concussion. There are conflicting findings as to whether or not cognitive rest is effective in promoting recovery following concussion with limited evidence supporting how cognitive rest should be implemented. Specifically, current recommendations do not provide information about the amount or intensity of cognitive activity that should be completed following concussion.

Objectives: 1) to determine the association between the amount, intensity and type of school class (math and science, or arts, language and other) for each session of cognitive activity and an acute increase in concussion symptoms or difficulty with task completion, 2) to determine for each individual, the relationship between group assignment (standard-of-care vs. cognitive activity intervention), sex, concussion history and age with difficulty returning to school (defined as reporting an increase in symptoms or more difficulty than usual with task completion on 20% or more of all sessions of school-related cognitive activity).

Design: Observational

Setting: High school sports medicine center

Patients or Other Participants: Forty high school athletes diagnosed with concussions were enrolled in the study (27 males, 13 females, age: 15.7 ± 1.1, height: 175.3 ± 9.1 cm, weight: 69.5 ± 34.2 kg).

Interventions: Based on the assignment of their high school, athletes who sustained a concussion and enrolled in the study were assigned to the standard-of-care or intervention group. Both groups recorded their school-related cognitive activity from the time of injury until they were deemed recovered. Intervention group participants received instructions on how much cognitive activity to complete on a daily basis, while the standard-of-care group followed instructions given to them by their healthcare providers.

Main Outcome Measures: Amount of cognitive activity, intensity of cognitive activity, acute change in concussion symptoms, difficulty with cognitive task, difficulty with school, history of concussion, sex and age.

Results: The cumulative amount of cognitive activity per day was significantly associated with an increase in symptoms following that session of cognitive activity ($p<0.01$). The intensity of the activity was significantly associated with reports of difficulty with task completion ($p=0.01$). There were no statistically significant associations between the length of a session of cognitive activity or the type of class and an increase in symptoms or report of difficulty with task completion ($p>0.05$). There were no statistically significant associations between group, sex, previous concussions or age and difficulty with school ($p>0.05$).

Conclusions: Limiting the amount of cognitive activity per day and intensity of school-related cognitive activity may help limit acute, adverse effects of student learning and performance. Academic accommodations that modify the intensity of the activity (e.g. use of audiotapes or note-takers) may be more effective in managing difficulties with returning to school, than

accommodations that modify the amount of sessions of cognitive activity (e.g. allowing frequent breaks or rests as needed).

Key Words: TBI, academic accommodations, school recommendations

Introduction

Sport and recreation related traumatic brain injuries affect millions annually in the United States.[1] Concussions are a form of traumatic brain injury, which can have a negative effect on several aspects of the patient's life, including home, school, social and sports or recreation.[130] Concussions often result in a series of symptoms, neurocognitive deficits and balance deficits, which can make activities of daily living more difficult than usual. Younger athletes typically take longer to recover from concussions, likely because their brains have not yet fully developed.[10] Younger athletes often face the challenge of having to return to school following concussion.

Returning to school following concussion is troublesome, because concussions can impair an individual's ability to learn.[12] Some concussion symptoms, such as difficulty concentrating, headaches, fatigue, feeling "in a fog" and "feeling slowed down" can cause difficulty learning. Additionally, attempting to complete too much cognitive activity too soon following concussion can increase the neurometabolic demands on a healing brain,[12] which can in turn increase concussion symptoms. High school students have a high academic demand with a large breadth and depth of curriculum in addition to extracurricular activities, which can cause more significant post-injury academic difficulties compared to students in younger grades.[130]

Cognitive rest is suggested as a treatment for concussion.[2] However, there are conflicting findings as to whether or not cognitive rest is effective in promoting recovery following concussion.[14,15,111] Additionally, there are very few recommendations about how cognitive rest should be implemented. Specifically, current recommendations do not provide information about the amount or intensity of cognitive activity that should be completed following concussion. In order to make evidence-based recommendations and optimize the utility of cognitive rest following concussion, the influence of the amount and intensity of cognitive activity following concussion must be established.

There were two main purposes of this study. The primary purpose was to determine the association between the amount, intensity and type of class (math and science, or arts, language and other) for each session of cognitive activity and an acute increase in concussion symptoms or difficulty with task completion. We hypothesized that sessions with higher amounts and intensities of cognitive activity, and math and science classes would be most likely to result in an acute increase in concussion symptoms and difficulty with task completion. Our second purpose was to determine for each individual, the relationship between group assignment (standard-of-care vs. cognitive activity intervention), sex, concussion history and age with difficulty returning to school (defined as reporting an increase in symptoms or more difficulty than usual with task completion on 20% or more of all sessions of school-related cognitive activity).

Methods

Study Participants

Forty high school athletes who were diagnosed with a sport-related concussion at one of four high schools over the course of the 2014-2015 academic year were included in the study. Athletes from the following sports were baseline tested prior to participation in sport: football, soccer, field hockey, volleyball, basketball, wrestling, lacrosse, baseball, softball and cheerleading. Institutional Review Board approved informed consent documents were delivered to high school players and their parents/legal custodians at baseline testing.

Measurements and Instrumentation

All participants were administered a series of assessments and a demographic form as part of a baseline test, prior to the beginning of their athletic season. Participants consented, assented and given parental permission (if applicable) to participate in the study that sustained a concussion, participated in an initial meeting, which was held in person, or over the phone, within 24 hours of their injury. During the initial meeting, all participants were given a "Study Workbook," which allowed them to keep track of their symptoms, and cognitive activity over the next several days to several weeks.

The standard-of-care group received the standard-of-care, meaning that they simply followed instructions given to them by their physician or athletic trainer and were not given any information about how much activity to complete by members of the research team. Concussed participants in the intervention group received a gradual return to cognitive activity intervention, detailing how much school-related cognitive activity he or she should complete on a daily basis. All participants, regardless of group, talked to a member of the research team on a daily basis, either in person or over the phone. These "daily check-ins" were conducted to ensure that the school-related cognitive activity surveys were being completed properly by the participants, and for identifying when the participant was symptom free (when compared to baseline SCAT3 symptom scores). Once the participant had been symptom free for 24 hours, he or she was administered a post-injury assessment, where they were reassessed on baseline measures (SCAT3, the King-Devick test, near-point convergence and a computerized neurocognitive test, CNS Vital Signs) to determine whether or not they had reached recovery. The post-injury assessments were administered at the participant's high school by their athletic trainer or a member of the research team. Once an athlete was deemed recovered, they no longer completed the school-related cognitive activity surveys.

Demographic Information

Demographic information for all participants was collected during baseline testing, as part of a paper or online survey. Information collected included age, sex, height, weight, academic year, and self- reported history of learning disability, attention deficit hyperactivity disorder, migraines, epilepsy, seizures or psychiatric conditions.

Intervention

The cognitive activity intervention involved scaling the amount of cognitive activity that the individual participated in on a daily basis. The intervention included 5 stages (Table 6.1). Each stage recommended a certain environment (home or at school), the amount of cognitive activity to be completed in one sitting, the amount of rest to take after each session of cognitive activity and the total amount of cognitive activity to complete in one day. Participants were instructed to complete stage one at home, which included a maximum of 20 minutes of cognitive activity at a time, followed by a 30 minute break, with a total of no more than 1 hour of cognitive activity during the day. If the participant experienced any increase in symptoms while completing cognitive activity, he or she was instructed to stop their activity at that time. Once the participant's symptoms returned to their pre-cognitive activity level, he or she was instructed to take the suggested rest break before beginning any more cognitive activity. Once participants were able to complete the maximum recommended amount of cognitive activity in a given day without any of their sessions of cognitive activity resulting in an overall increase in symptoms greater than 6 or any one symptom increasing greater than 3 points, then he or she could progress to the next stage of the intervention. Participants were also given specific recommendations according to the symptoms they were experiencing, based on recommendations of Halstead et al.[120], which are described in Table 6.2.

School-related Cognitive Activity Surveys

All participants were asked to complete school-related cognitive activity surveys every day following their concussion until they were deemed recovered. Participants were given the opportunity to complete the school-related cognitive activity surveys on a series of paper surveys, online using Qualtrics surveys, or through a combination of paper and online surveys. A variety of methods were available to the participants in order to lessen the burden to participants and to increase compliance. Prior to each session of school-related cognitive activity, participants were asked to complete the abbreviated symptom checklist, which asked them to rate their symptoms on a scale of 0-10 (symptoms: headache, fatigue, concentration problems, irritability, fogginess and sensitivity to light or noise). Participants were then asked to complete the abbreviated symptoms checklist immediately after concluding each session of cognitive activity. They were also asked how long each session of cognitive activity lasted, whether the activity was completed at home or at school, and what class the session of cognitive activity was related to (e.g. math, science, or history). Additionally, they were asked what tasks they completed (e.g. reading, studying, listening to a lecture, taking notes, doing group work), and whether the task was more difficult that usual.

Data Reduction

Data entry and data reduction methods are described in Table 6.3

Statistical Analyses

All statistical analyses were performed in SAS (Version 9.3; SAS Institute, Inc, Cary, North Carolina). Results are considered significant at an a priori alpha level of 0.05. To determine the association between the amount and intensity of cognitive activity and acute change in concussion symptoms and difficulty with the task, general estimating equations were used. Change in symptoms was a dichotomous variable with the levels of 1) no change or decrease in the number or severity of symptoms during the session of cognitive activity, 2) increase in number and/or severity symptoms during the session of cognitive activity. Difficulty with the task was a dichotomous variable with the levels of 1) no difficulty with any of the tasks completed during the session 2) difficulty with one or more of the tasks completed during the session. We analyzed both the length of a session of school-related cognitive activity, and the cumulative length in minutes that the participant had completed of school-related cognitive activity so far that day. Remaining variables included the intensity of cognitive activity, which had the following levels: 1) low 2) high, and type of class for which the work was completed: 1) math and science, 2) arts, language and other- English, foreign language, history, art, physical education and technical. In order to address our secondary aim of determining the association between sex, age and previous concussion and difficulty with school, chi-square analyses were utilized. Age was treated as a dichotomous variable with 2 levels (14-15, and 16-18).

Results

There were a total of 970 sessions of school-related cognitive activity among the 40 participants in this study. We are missing symptom information for 28 (<3%) sessions of cognitive activity. Therefore, 942 sessions of school-related cognitive activity were used for analyses. The cumulative amount of cognitive activity per day was significantly associated with an increase in symptoms following that session of cognitive activity ($p<0.01$; Tables 6.4 and 6.5). The intensity of the activity was significantly associated with reports of difficulty with task completion ($p=0.01$), and there were no statistically significant associations between the length of a session of cognitive activity or the type of class and an increase in symptoms or report of difficulty with task completion ($p>0.05$; Table 6.4 and Table 6.6). There were no statistically significant associations between group, sex, previous concussions or age and difficulty with school ($p>0.05$; Table 6.7).

Discussion

We observed an association between cumulative school-related cognitive activity per day and acute increase in concussion symptoms, and between the intensity of school-related cognitive activity and reported difficulty with task completion. To our knowledge, this is the first study that has assessed patient reported change in symptoms following sessions of school-related cognitive activity. We hypothesized that higher amounts and higher intensities of school-related cognitive activity would result in a greater likelihood of increased symptoms. Surprisingly, cumulative cognitive activity throughout the day was associated with increased symptoms, but the length of each session of cognitive activity was not associated with an acute increase in symptoms. It appears that the first two sessions of cognitive activity for participants each day were most likely to result in an increase in concussion symptoms (24% and 23% respectively). Therefore, participants may need to complete less important tasks earlier in the day, as they adjust to completing cognitive activity. Additionally, intensity was associated with participants reporting an increased difficulty in task completion compared to before sustaining their concussion, but was not associated with an increase in concussion symptoms. Concussed participants were 43% more likely to report difficulty with high intensity tasks compared to low intensity tasks. This suggests that while high intensity tasks may not result in increased symptoms, they are typically more challenging for patients than they were prior to the concussion. Future research should examine the influence of the intensity of school-related tasks on performance-based academic outcomes following concussion.

Several recommendations have been made for academic accommodations following concussion, including frequent breaks or rests as needed, use of audiotapes or books, avoiding testing or completion of major projects, providing extra time for assignments, considering the use of note-takers or pre-printed notes or allowing a shortened school day. [120] Our findings suggest that the cumulative amount of schoolwork per day and the intensity of the activity may have the biggest influence on difficulties with returning to school. Therefore, the accommodations that modify the intensity of the activity, such as use of audiotapes or books, avoidance of testing and use of note-takers or pre-printed notes may be more effective in managing difficulties with returning to school, than accommodations that modify the length of sessions of cognitive activity, such as allowing frequent breaks or rests as needed. While shortening the sessions of cognitive activity may aid in minimizing increases in symptoms for the first couple sessions of cognitive activity, it is not likely to provide long-term benefits, or aid in minimizing increased difficulty with task completion.

While previous studies have demonstrated that the type of class has an influence on difficulty with task completion, we did not observe an association between the type of class for which the schoolwork was being completed and increase in symptoms or reporting difficulty with task completion. Middle school and high school students have reported difficulties with math, language arts, science and social studies following concussion. [12,130] We did not have enough observations to examine differences between individual classes, so we compared math and science classes to arts, language and other classes (English, foreign language, history, art, physical education and technical). This could have led to our discrepancy in findings. Other possibilities for discrepancies in findings include differences in school systems, teaching styles, learning styles, and age differences.

When analyzing our entire sample, we did not observe an association between group, age, sex, or previous concussions and difficulty with returning to school. Sex, age and previous history of concussion have been shown to contribute to recovery following concussion,[124] but do not appear to have an influence on whether or not individuals have difficulty with school following concussion. Therefore, it seems as though other factors, such as the cumulative amount and intensity of activity, should be taken into account when developing plans for academic accommodations. Future research should explore other factors that may influence difficulty with school following concussion. It is likely that neurocognitive, visual or vestibular deficits at the time of injury may be predictive of school-problems throughout the recovery process. Cutoff scores for symptom clusters and neurocognitive domains have been established for predicting protracted recovery[9] and may be useful in predicting difficulty with school as well. If predictors of school-problems can be identified, interventions and treatment strategies can be developed to limit difficulty with returning to school.

We must acknowledge some limitations of the study. We are relying on self-report measures of symptoms, cognitive activity and physical activity. We assume that participants were honest and truthful in their reporting of symptoms and the amount of cognitive and physical activity they were completing. We did not record what instructions were given to participants in the standard-of-care group. We also may have had insufficient power to address some of our aims. These findings should be interpreted as preliminary, and future research should continue to explore factors affecting recover following concussion.

Overall, our findings suggest that the cumulative amount of cognitive activity per day and the intensity of cognitive activities have an influence on increases in symptoms and difficulty with task completion following concussion. When providing academic accommodations to patients following concussion, the overall amount of cognitive activity completed per day is likely more important to limit than each individual session of cognitive activity. Also, limiting higher intensity tasks, such as taking notes, completing practice problems and studying may be an effective strategy in limiting difficulties with returning to school. Future research should examine performance based academic outcomes following concussion. Limiting the length and intensity of school-related cognitive activity per day in the initial stage following concussion may help limit adverse effects of student learning and performance.

Table 6.1. Stages of School-Related Cognitive Activity Intervention

Stage	Environment	Only complete this much cognitive activity in one sitting:	Rest for at least this long following each session of cognitive activity:	Complete no more than a total of this much cognitive activity each day:
1	Home	20 minutes	30 minutes	1 hour
2	Home	45 minutes	20 minutes	3 hours
3	School	2 hours	10 minutes	5 hours
4	School	4 hours	10 minutes	7 hours
5	School	8 hours	--	--

Table 6.2 Recommendations Based on Halstead et al. [120] used in intervention

Symptom	Recommendations
Headache	• Take frequent breaks throughout the day • Rest in a quiet room if symptoms increase
Dizziness	• Leave each class early in order to allow extra time to get to the next class
Visual symptoms (i.e. blurred vision)	• Reduce the brightness on computer or phone screens • Wear sunglasses if necessary • Avoid fluorescent lights
Noise sensitivity	• Eat lunch in a quiet area with a classmate • Use earplugs if needed
Difficulty concentrating or remembering	• Postpone all exams
Sleep disturbance	• Late start to day to catch up on sleep

Table 6.3 Data Reduction

Source	Data Entry Method
Demographic Information	Exported directly from the online platform in which they were administered (CNS Vital Signs)
School-related Cognitive Activity Surveys (completed online)	Scores exported directly from Qualtrics
All other data	Hand entered using double entry method
Source	**Data Reduction Method**
School-work Surveys	**Intensity of session**: **Low-** all tasks during the session were passive activities (reading, listening to a lecture, watching a movie, completing a physical activity) **High-** one or more tasks during the session were active activities (writing essays or short answers, group work, taking notes, math problems, studying for quizzes and exams, taking quizzes and exams)
	Cumulative cognitive activity per session: Sum of the length of the session of cognitive activity and the length of all previous sessions of cognitive activity the participant had completed that day
	Difficulty returning to school: **No-** Participants reporting an increase in symptoms or more difficulty than usual with task completion on less than 20% of their sessions of school-related cognitive activity. **Yes-** Participants reporting an increase in symptoms or more difficulty than usual with task completion on 20% or more of their sessions of school-related cognitive activity.

Table 6.4 Results of General Estimating Equations examining association between characteristics of cognitive activity and increase in symptoms or difficulty with task

Characteristics	Increase in Symptoms Odds Ratio (95%CI)	Difficulty with Task Odds Ratio (95%CI)
Length of session of cognitive activity (per 10 minutes)	1.01 (0.99, 1.02) p=0.38	1.00 (0.98, 1.00) p=0.21
Cumulative amount of cognitive activity per day (per 1 hour increase)	**1.05 (0.77, 0.95) p<0.01**	1.01 (0.92, 1.11) p=0.82
Intensity of activity (low vs. high)	0.96 (0.67, 1.39) p=0.84	**0.57 (0.37, 0.90) p=0.01**
Class (math and science vs. arts, language and other)	0.65 (0.40, 1.03) p=0.07	0.70 (0.44, 1.12) p=0.14

Table 6.5 Reports of increased symptoms following each session of cognitive activity

Order of session (per day)	Number of sessions	n (Percent) of sessions resulting in increased symptoms	n (Percent) of sessions resulting in no change or decreased symptoms
1st	214	51 (23.83)	163 (76.17)
2nd	208	48 (23.08)	160 (76.92)
3rd	195	37 (18.97)	158 (81.03)
4th	156	27 (17.31)	129 (82.69)
5th	91	8 (8.79)	83 (91.29)
6th	44	5 (11.36)	39 (88.64)
7th	22	2 (9.09)	20 (90.91)
8th	7	0 (0)	7 (100.00)
9th	4	0 (0)	4 (100.00)

Table 6.6. Participant report of increase in symptoms by class

Class	Percentage Resulting in Increased Symptoms
Math & Science	
Math	22 (23/104)
Science	14 (24/177)
Arts, Language & Other	
History	33 (56/170)
English	31 (15/48)
Foreign Language	29 (45/156)
Technical	19 (6/32)
Art	17 (1/6)
Music	0 (0/1)

Table 6.7 Results of Chi-Square analyses examining association between characteristics of participants and difficulty with school

Participant Characteristics	**n**	**No Difficulty with School** n (Percent)	**Difficulty with School** n (Percent)	**Chi-Square P value**
Group				
Standard-of-Care	20	12 (30)	8 (20)	X^2=0.40, p=0.53
Intervention	20	10 (25)	10 (25)	
Sex				
Males	27	17 (42.5)	10 (25)	X^2=2.13, p=0.15
Females	13	5 (12.5)	8 (20)	
Previous Concussions				
0	30	16 (40)	14 (35)	X^2=0.13, p=0.71
1+	10	6 (15)	4 (10)	
Age				
14-15	17	11 (27.5)	6 (15)	X^2=1.13, p=0.29
16+	23	11 (27.5)	12 (30)	

APPENDIX A: INTENSITY OF COGNITIVE ACTIVITY

Cognitive activities were categorized in the following manner:

Intensity of Activity	Activities Include
Low	Passive Activities- Reading Listening to a lecture Watching a movie Completing a physical activity
High	Active Activities- Writing essays or short answers Group work Taking notes Math problems Studying for quizzes and exams Taking quizzes and exams

If a session of cognitive activity included multiple low intensity activities, the session was categorized as low intensity.
If a session of cognitive activity included at least one high intensity activity, it was categorized as high intensity.

APPENDIX B: INTERVENTION

The stages of the intervention and possible additional recommendations are included below. An example of the information to be given to the participants is included on the next page. The top portion of the page will be given to ALL participants, while the second half of the page (indicated by the line) is an example of the information that would be give to a participant who is completing the first stage of the intervention.

We also suggest you:

Stage	Environment	Only complete this much cognitive activity in one sitting:	Rest for at least this long following each session of cognitive activity:	Complete no more than a total of this much cognitive activity each day:
1	Home	20 minutes	30 minutes	1 hour
2	Home	45 minutes	20 minutes	3 hours
3	School	2 hours	10 minutes	5 hours
4	School	4 hours	10 minutes	7 hours
5	School	8 hours	--	--

☐ Take frequent breaks throughout the day

☐ Rest in your room or the nurse's office if your symptoms increase

☐ Leave each class early to allow you extra time to get to the next class

☐ Reduce the brightness on computer or phone screens

☐ Wear sunglasses and avoid fluorescent lights

☐ Eat lunch in a quiet area with a classmate

☐ Use earplugs

☐ Postpone all exams

☐ Allow for late start to your day to catch up on sleep

Remember to pay attention to how you feel when you are completing cognitive activity. Fill out the symptom checklist before and after all cognitive activity. If you notice your symptoms are returning or getting worse, stop the activity and take a break.

APPENDIX C: STUDY WORKBOOK

Your initials: ___________

Nighttime Survey

Rate the symptoms below based on how you feel RIGHT NOW. Circle one of the numbers for each symptom ranging from 0 (not present) to 10 (highest symptom level).

Headache	0	1	2	3	4	5	6	7	8	9	10
Fatigue	0	1	2	3	4	5	6	7	8	9	10
Concentration problems	0	1	2	3	4	5	6	7	8	9	10
Irritability	0	1	2	3	4	5	6	7	8	9	10
Fogginess	0	1	2	3	4	5	6	7	8	9	10
Light/noise sensitivity	0	1	2	3	4	5	6	7	8	9	10

Symptoms

How do you feel?

"You should score yourself on the following symptoms, based on how you feel now".

	none	mild		moderate		severe	
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Sensitivity to light	0	1	2	3	4	5	6
Sensitivity to noise	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Feeling like "in a fog"	0	1	2	3	4	5	6
"Don't feel right"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Fatigue or low energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Trouble falling asleep	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6

Physical Activity Diary

Directions:

Write the number of the category corresponding to the dominant activity you completed for each 15-minute interval throughout the day. If in doubt, write a letter in the space provided and then write the letter at the bottom, followed by the activity you completed during that interval.

Hour	00-15	15-30	31-45	46-59
6 am				
7 am				
8 am				
9 am				
10 am				
11 am				
12 (noon)				
13 (1 pm)				
14 (2 pm)				
15 (3 pm)				
16 (4 pm)				
17 (5 pm)				
18 (6 pm)				
19 (7 pm)				
20 (8 pm)				
21 (9 pm)				
22 (10 pm)				
23 (11 pm)				
24 (12 am)				
1 (1 am)				
2 (2 am)				
3 (3 am)				
4 (4 am)				
5 (5 am)				

Category	Example of Activities
1	Sleeping, resting in bed
2	Sitting, eating, writing, listening
3	Standing, washing, combing
4	Light home activities, getting dressed, taking a shower
5	Walking outdoors, light manual work, house chores
6	Leisure activities, sports and manual work of low intensity (golf, ping pong, bicycling <15 km/hr)
7	Leisure activities, sports and manual work of moderate intensity (jogging, hiking)
8	Leisure activities, sports and manual work of high intensity (running, soccer, tennis, bicycling >16 km/hr)
9	Sports activities and work of very high to maximal intensity (competitive running, etc.)

Write comments or letter codes here:

Cognitive Activity Diary

Read each of the items below. If you have not yet completed the activity today before completing this survey, place an "X" in the first column, "I did not complete this activity". If you have completed one of the activities below before starting this survey, then place an "X" in the second column if it was NOT more difficult than it was before you had a concussion, and place an "X" in the third column if it was more difficult than it was before you had a concussion.

Activity	I did not complete this activity.	I did this and it was **NOT** more difficult than usual.	I did this and it **WAS** more difficult than usual.
Watched television			
Listened to music			
Played video games or games on an electronic device (iPad or computer)			
Texted, tweeted or updated a social media site (Facebook, vine, instagram, etc.)			
Surfed the internet or social media sites			
Talked on the phone			
Read			
Played a musical instrument			

Please describe each of the non-school related cognitive activities that you have completed so far today below. Cognitive activities are included above in the chart (e.g. watching television or listening to music).

Describe activity:	**How long did you do this for?**

Comments:

<u>Pre-Schoolwork Survey</u>

Rate the symptoms below based on how you feel right now, BEFORE completing your schoolwork. Circle one of the numbers for each symptom ranging from 0 (not present) to 10 (highest symptom level).

Headache	0	1	2	3	4	5	6	7	8	9	10
Fatigue	0	1	2	3	4	5	6	7	8	9	10
Concentration problems	0	1	2	3	4	5	6	7	8	9	10
Irritability	0	1	2	3	4	5	6	7	8	9	10
Fogginess	0	1	2	3	4	5	6	7	8	9	10
Light/noise sensitivity	0	1	2	3	4	5	6	7	8	9	10

What time are you starting your activity? _____________________

What type of activity are you about to complete (brief description)?

Post-Schoolwork Survey

Rate the symptoms below based on how you feel right now, AFTER completing your schoolwork. Circle one of the numbers for each symptom ranging from 0 (not present) to 10 (highest symptom level).

Headache	0	1	2	3	4	5	6	7	8	9	10
Fatigue	0	1	2	3	4	5	6	7	8	9	10
Concentration problems	0	1	2	3	4	5	6	7	8	9	10
Irritability	0	1	2	3	4	5	6	7	8	9	10
Fogginess	0	1	2	3	4	5	6	7	8	9	10
Light/noise sensitivity	0	1	2	3	4	5	6	7	8	9	10

What time did you stop your activity? ____________________

What type of activity did you complete? (Circle the appropriate response)

Schoolwork or homework at home

Went to classes at school

What class did you attend, or what class were you completing schoolwork for? (Circle the appropriate response)

Math

Science

English

Foreign Language

History

Art

Music

Physical education

Technical (home economics, woodshop, etc.)

Read each of the items below. If you did not JUST complete the activity described, place an “X” in the first column, "I did not just complete this activity". If you have JUST completed one of the activities below, then place an “X” in the second column if it was NOT more difficult than usual and place an “X” in the third column if it was more difficult than it was before you had a concussion.

Activity	I did not complete this activity.	I did this and it was **NOT** more difficult than usual.	I did this and it **WAS** more difficult than usual.
Reading			
Studying			
Listened to a lecture			
Took notes			
Did group work			
Did practice problems			
Watched a movie			
Took a quiz			
Took an exam			
Wrote a short answer or a paper			
Complete a physical activity (running, pottery, workshop, etc.)			

Concussion Recovery Information

Tracking your physical and cognitive activity may help you recover from your concussion. We are asking you to complete 2 short surveys every day. Instructions for keeping track of your activities are located below.

What surveys should I complete every day?

1. **Night Time Survey**- complete at the end of the day, as close to when you are trying to fall asleep as possible (takes about 5-10 minutes)
2. **School Work Surveys (see below)**

What surveys should I complete if I do school work, such as homework, studying or going to class?

1. **PRE School Work Survey-** complete this before any type of school related activity (takes about 30 seconds)
2. **POST School Work Survey-** complete this any type you stop a school related activity, or you are switching participants that you are working on for school (takes about 1-2 minutes)

How much activity am I allowed to do?

You should AVOID:

- Watching television
- Playing video games or games on an electronic device (iPad or computer)
- Texting, tweeting, or updating a social media site (Facebook, Vine, Instagram, etc.)
- Surfing the internet or social media sites

You MAY complete:

- **20 minutes of schoolwork:** You may complete up to 20 minutes of schoolwork or school related activity in one sitting at home.
- **30-minute break:** You should take at least a 30-minute break after completing 20 minutes of schoolwork.
- **1-hour total of schoolwork:** You should complete no more than 1-hour total of schoolwork.

— If you notice your symptoms are getting worse or you are getting new symptoms while completing schoolwork, then stop and take a 30-minute break.

— Make sure that your symptoms get better before starting any new activity:
  - Individual symptoms should return to within **3 points** of what they were before you started the activity.
  - Overall symptom scores should return to within **6 points** of what they were before you started the activity.

What if I have questions about what to do?

If you have questions, you should contact:

APPENDIX D: DEMOGRAPHIC INFORMATION

Section I: Demographic Information

Name ____________________________ School __________________________

Height:_________ Weight:__________ Age:_______

Academic Year: ☐Freshman ☐Sophomore ☐Junior ☐Senior

Section II: Sport Participation

Complete this section regarding participation in sports.

Which of the following sports do you participate in at your high school?

☐ Field Hockey
☐ Football
☐ Soccer
☐ Volleyball
☐ Basketball
☐ Wrestling
☐ Swimming
☐ Lacrosse
☐ Softball
☐ Baseball
☐ Tennis
☐ Other: ___________________________

Which of the following sports do you participate in outside of your high school (such as on recreational teams or travel teams)?

☐ Field Hockey
☐ Football
☐ Soccer
☐ Volleyball
☐ Basketball
☐ Wrestling
☐ Swimming
☐ Lacrosse
☐ Softball
☐ Baseball
☐ Tennis
☐ Other: ___________________________

Section III: Concussion History

A. If you have been diagnosed with a concussion by a medical professional (such as an athletic trainer or physician) fill in the information regarding the concussion(s) in the chart below. If you have not been diagnosed with a concussion skip to Section IV.
If you have been diagnosed with only 1 concussion, only fill in the first column. If you have been diagnosed with 2 or 3 concussions, fill in the first column with your most recent concussion, and the 2nd (and 3rd) column with the concussion(s) that occurred before your most recent concussion. If you have had more than 3 concussions, please write how many you have been diagnosed with here: __________ and fill in the chart with information about your 3 most recent concussions.

	Concussion # 1 (Most recent)	Concussion #2	Concussion #3
Approximate date of concussion (Month, Year)			
Did the concussion occur while participating in sport?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
How many days did you miss from school or sports because of the concussion?			
Check the box if your concussion resulted in:	☐ Loss of consciousness ☐ Trouble remembering ☐ Dizziness ☐ Confusion	☐ Loss of consciousness ☐ Trouble remembering ☐ Dizziness ☐ Confusion	☐ Loss of consciousness ☐ Trouble remembering ☐ Dizziness ☐ Confusion

Section IV: General Medical History.

Check yes or no for each of the questions below.

I have received speech therapy.	☐ Yes	☐ No
I have attended special education classes.	☐ Yes	☐ No
I have repeated one or more years of school.	☐ Yes	☐ No
I have been diagnosed with a learning disability.	☐ Yes	☐ No
I have been diagnosed with ADHD.	☐ Yes	☐ No
I have been treated for headaches by a physician	☐ Yes	☐ No
I have been treated for migraine headaches by a physician.	☐ Yes	☐ No
I have been treated for epilepsy or seizures.	☐ Yes	☐ No
I have a history of brain surgery.	☐ Yes	☐ No
I have a history of meningitis.	☐ Yes	☐ No
I have been treated for substance or alcohol abuse.	☐ Yes	☐ No
I have been treated for depression and anxiety.	☐ Yes	☐ No

APPENDIX E: SPORT CONCUSSION ASSESSMENT TOOL 3RD EDITION

SCAT 3

SCAT3™

Sport Concussion Assessment Tool – 3rd Edition

For use by medical professionals only

Name

Date/Time of Injury:
Date of Assessment:

Examiner:

What is the SCAT3?[1]

The SCAT3 is a standardized tool for evaluating injured athletes for concussion and can be used in athletes aged from 13 years and older. It supersedes the original SCAT and the SCAT2 published in 2005 and 2009, respectively[2]. For younger persons, ages 12 and under, please use the Child SCAT3. The SCAT3 is designed for use by medical professionals. If you are not qualified, please use the Sport Concussion Recognition Tool[1]. Preseason baseline testing with the SCAT3 can be helpful for interpreting post-injury test scores.

Specific instructions for use of the SCAT3 are provided on page 3. If you are not familiar with the SCAT3, please read through these instructions carefully. This tool may be freely copied in its current form for distribution to individuals, teams, groups and organizations. Any revision or any reproduction in a digital form requires approval by the Concussion in Sport Group.

NOTE: The diagnosis of a concussion is a clinical judgment, ideally made by a medical professional. The SCAT3 should not be used solely to make, or exclude, the diagnosis of concussion in the absence of clinical judgement. An athlete may have a concussion even if their SCAT3 is "normal".

What is a concussion?

A concussion is a disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific signs and/or symptoms (some examples listed below) and most often does not involve loss of consciousness. Concussion should be suspected in the presence of **any one or more** of the following:

- Symptoms (e.g., headache), or
- Physical signs (e.g., unsteadiness), or
- Impaired brain function (e.g. confusion) or
- Abnormal behaviour (e.g., change in personality).

SIDELINE ASSESSMENT

Indications for Emergency Management

NOTE: A hit to the head can sometimes be associated with a more serious brain injury. Any of the following warrants consideration of activating emergency procedures and urgent transportation to the nearest hospital:

- Glasgow Coma score less than 15
- Deteriorating mental status
- Potential spinal injury
- Progressive, worsening symptoms or new neurologic signs

Potential signs of concussion?

If any of the following signs are observed after a direct or indirect blow to the head, the athlete should stop participation, be evaluated by a medical professional and **should not be permitted to return to sport the same day** if a concussion is suspected.

Any loss of consciousness?	Y	N
"If so, how long?" ______		
Balance or motor incoordination (stumbles, slow/laboured movements, etc.)?	Y	N
Disorientation or confusion (inability to respond appropriately to questions)?	Y	N
Loss of memory:	Y	N
"If so, how long?" ______		
"Before or after the injury?" ______		
Blank or vacant look:	Y	N
Visible facial injury in combination with any of the above:	Y	N

1 Glasgow coma scale (GCS)

Best eye response (E)	
No eye opening	1
Eye opening in response to pain	2
Eye opening to speech	3
Eyes opening spontaneously	4
Best verbal response (V)	
No verbal response	1
Incomprehensible sounds	2
Inappropriate words	3
Confused	4
Oriented	5
Best motor response (M)	
No motor response	1
Extension to pain	2
Abnormal flexion to pain	3
Flexion/Withdrawal to pain	4
Localizes to pain	5
Obeys commands	6
Glasgow Coma score (E + V + M)	of 15

GCS should be recorded for all athletes in case of subsequent deterioration.

2 Maddocks Score[3]

"I am going to ask you a few questions, please listen carefully and give your best effort."

Modified Maddocks questions (1 point for each correct answer)

What venue are we at today?	0	1
Which half is it now?	0	1
Who scored last in this match?	0	1
What team did you play last week/game?	0	1
Did your team win the last game?	0	1
Maddocks score		of 5

Maddocks score is validated for sideline diagnosis of concussion only and is not used for serial testing.

Notes: Mechanism of Injury ("tell me what happened"?):

Any athlete with a suspected concussion should be REMOVED FROM PLAY, medically assessed, monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle until cleared to do so by a medical professional. No athlete diagnosed with concussion should be returned to sports participation on the day of Injury.

BACKGROUND

Name: ______ Date: ______

Examiner: ______

Sport/team/school: ______ Date/time of injury: ______

Age: ______ Gender: ☐ M ☐ F

Years of education completed: ______

Dominant hand: ☐ right ☐ left ☐ neither

How many concussions do you think you have had in the past? ______

When was the most recent concussion? ______

How long was your recovery from the most recent concussion? ______

Have you ever been hospitalized or had medical imaging done for a head injury? ☐ Y ☐ N

Have you ever been diagnosed with headaches or migraines? ☐ Y ☐ N

Do you have a learning disability, dyslexia, ADD/ADHD? ☐ Y ☐ N

Have you ever been diagnosed with depression, anxiety or other psychiatric disorder? ☐ Y ☐ N

Has anyone in your family ever been diagnosed with any of these problems? ☐ Y ☐ N

Are you on any medications? If yes, please list: ☐ Y ☐ N

SCAT3 to be done in resting state. Best done 10 or more minutes post excercise.

SYMPTOM EVALUATION

3 How do you feel?

"You should score yourself on the following symptoms, based on how you feel now".

	none	mild		moderate		severe	
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Sensitivity to light	0	1	2	3	4	5	6
Sensitivity to noise	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Feeling like "in a fog"	0	1	2	3	4	5	6
"Don't feel right"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Fatigue or low energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Trouble falling asleep	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6

Total number of symptoms (Maximum possible 22) ______

Symptom severity score (Maximum possible 132) ______

Do the symptoms get worse with physical activity? ☐ Y ☐ N

Do the symptoms get worse with mental activity? ☐ Y ☐ N

☐ self rated ☐ self rated and clinician monitored

☐ clinician interview ☐ self rated with parent input

Overall rating: If you know the athlete well prior to the injury, how different is the athlete acting compared to his/her usual self?

Please circle one response:

no different | very different | unsure | N/A

Scoring on the SCAT3 should not be used as a stand-alone method to diagnose concussion, measure recovery or make decisions about an athlete's readiness to return to competition after concussion. Since signs and symptoms may evolve over time, it is important to consider repeat evaluation in the acute assessment of concussion.

COGNITIVE & PHYSICAL EVALUATION

4 Cognitive assessment

Standardized Assessment of Concussion (SAC)[4]

Orientation (1 point for each correct answer)

What month is it?	0	1
What is the date today?	0	1
What is the day of the week?	0	1
What year is it?	0	1
What time is it right now? (within 1 hour)	0	1
Orientation score		of 5

Immediate memory

List	Trial 1		Trial 2		Trial 3		Alternative word list		
elbow	0	1	0	1	0	1	candle	baby	finger
apple	0	1	0	1	0	1	paper	monkey	penny
carpet	0	1	0	1	0	1	sugar	perfume	blanket
saddle	0	1	0	1	0	1	sandwich	sunset	lemon
bubble	0	1	0	1	0	1	wagon	iron	insect
Total									

Immediate memory score total ______ of 15

Concentration: Digits Backward

List	Trial 1		Alternative digit list		
4-9-3	0	1	6-2-9	5-2-6	4-1-5
3-8-1-4	0	1	3-2-7-9	1-7-9-5	4-9-6-8
6-2-9-7-1	0	1	1-5-2-8-6	3-8-5-2-7	6-1-8-4-3
7-1-8-4-6-2	0	1	5-3-9-1-4-8	8-3-1-9-6-4	7-2-4-8-5-6
Total of 4					

Concentration: Month in Reverse Order (1 pt. for entire sequence correct)

Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr-Mar-Feb-Jan 0 1

Concentration score ______ of 5

5 Neck Examination:

Range of motion Tenderness Upper and lower limb sensation & strength

Findings: ______

6 Balance examination

Do one or both of the following tests.

Footwear (shoes, barefoot, braces, tape, etc.) ______

Modified Balance Error Scoring System (BESS) testing[5]

Which foot was tested (i.e. which is the **non-dominant** foot) ☐ Left ☐ Right

Testing surface (hard floor, field, etc.) ______

Condition

Double leg stance: ______ Errors

Single leg stance (non-dominant foot): ______ Errors

Tandem stance (non-dominant foot at back): ______ Errors

And/Or

Tandem gait[6,7]

Time (best of 4 trials): ______ seconds

7 Coordination examination

Upper limb coordination

Which arm was tested: ☐ Left ☐ Right

Coordination score ______ of 1

8 SAC Delayed Recall[4]

Delayed recall score ______ of 5

APPENDIX F: STANDARDIZED INSTRUCTIONS FOR CNS VITAL SIGNS

- You are about to take a cognitive test that assesses your memory, concentration and reaction time.
- This test takes about 30 minutes to complete.
- Your goal for most of the tasks is to respond as quickly and accurately as possible. So, you want to get things right, but you also want to answer quickly.
- It is extremely important that you read the instructions before each of the assessments, and notify the test administrator if you have any questions about anything throughout the test.
- For this assessment, you will mainly be using the spacebar, the arrow keys and the numbers across the top of the keyboard. Try to avoid hitting the backspace button or the number pad, as the test will not recognize these keys.
- When the test asks for a password, it means you have completed the test. Please remain in your seat and remain quiet until told otherwise by the test administrator.
- At this time please make sure that your cell phone and all electronic devices are turned off or silenced. Do not talk to or disturb those around you during the test.
- Remember to read all instructions carefully and to be fast and accurate.
- You have been given earplugs, so that you are not distracted by noise during the test.
- Does anyone have any questions before we begin?
- You may now place your earplugs in your ear and begin the test.

APPENDIX G: CNS VITAL SIGNS SUBTESTS AND SCORE CALCULATIONS

Subtest	Description
Verbal Memory	Presented with 15 words and asked to remember them; later shown 30 words: 15 target words and 15 distractors and asked to identify the target words Measures verbal learning, immediate and delayed memory for words
Visual Memory	Presented with 15 geometric figures and asked to remember them; later shown 30 geometric figures: 15 target words and 15 distractors and asked to identify the target figures Measures visual learning, immediate and delayed memory for geometric shapes
Finger Tapping Test	Press the spacebar as many times as possible in 10 seconds, first with right index finger, then with left index finger Measures motor speed and fine motor control
Symbol Digit Coding	Given a key where a series of numbers correspond to a series of symbols and given an answer grid, where there is a symbol with the corresponding number missing; must fill in the corresponding number for as many symbols as possible in order Measures complex attention, visual-perceptual speed and information processing speed
Stroop Test	3 parts: 1) names of colors printed in black are presented and participant is asked to press the spacebar as quickly as possible when the word appears 2) names of colors are printed in color and participants are asked to respond when the color of the ink and the name of the word match (i.e. “red” written in red ink) 3) names of colors are printed in color and participants are asked to respond when the color of the ink and the name of the word do not match (i.e. “red” written in blue ink) Measures executive functioning, reaction time and information processing speed
Shifting Attention Test	Participant is shown a screen with a red circle and a blue square and then is shown a series of red or blue circles or squares and is asked to match them based on either color or shape Measures executive function, reaction time and information processing speed
Continuous Performance Test	Participant is shown 200 letters over the course of 5 minutes and is asked to respond only if the letter “B” is shown. Measures vigilance or sustained attention

CNS Vital Signs Domains, Score Calculations and Validity Indicators			
Domain	**Assesses the ability to:**	**Domain Score Calculation**	**Validity Indicator**
Verbal memory	Recognize, remember and retrieve words	Correct hits immediate + correct passes immediate + correct hits delayed + correct passes delayed	Verbal memory raw score >30
Visual memory	Recognize, remember and retrieve geometric figures	Correct hits immediate + correct passes immediate + correct hits delayed + correct passes delayed	Visual memory raw score > 30
Psychomotor speed	Perceives, attends, responds to visual-perceptual information and performs motor speed and fine motor coordination	Finger tapping test right taps average + finger tapping left taps average + Symbol Digit Coding correct responses	Finger tapping test: total taps > 40 or Symbol Digit Coding: >20 correct responses
Reaction time	Reacts to a simple and increasingly complex direction set	(Stroop complex reaction time correct + Stroop reaction time correct) / 2	Stroop: Simple reaction time < complex reaction time < Stroop reaction time
Complex attention	Track and respond to a variety of stimuli over lengthy periods of time and/or perform mental tasks requiring vigilance quickly and accurately	Stroop commission errors + Shifting attention test errors + Continuous performance test errors	Valid Stroop, continuous performance test and shifting attention test (correct > incorrect responses)
Cognitive flexibility	Adapt to rapidly changing and increasingly complex set of directions and/or manipulate information	Shifting attention test correct responses – Shifting attention test errors – Stroop commission errors	Valid stroop and shifting attention test (correct > incorrect responses)
Processing speed	Recognize and process information (perceiving,	Symbol digit coding correct	Symbol dgit coding: more than

	attending to incoming information, motor speed, fine motor coordination and visual-perceptual ability)	responses – symbol digit coding errors	20 correct responses
Executive functioning	Recognizes rules, categories and manages or navigates rapid decision making	Shifting attention test correct responses + shifting attention test errors	Shifting attention test: errors < correct responses

APPENDIX H: PATIENT SATISFACTION SURVEY
Adapted from the Short-Form Patient Satisfaction Questionnaire (PSQ-18)

Listed below are some things people say about health care. Please read each one carefully, keeping in mind the health care you received for your concussion. We are interested in your feelings, good and bad, about the health care you have received. The phrase "health care provider" includes physicians, physician assistants, athletic trainers and research assistants.

How strongly do you AGREE or DISAGREE with each of the following statements?
(Circle One Number on Each Line)

	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
1. Health care providers are good at explaining the reason for medical tests.	1	2	3	4	5
2. My health care provider has everything needed to provide complete medical care	1	2	3	4	5
3. The health care I have been receiving is just about perfect.	1	2	3	4	5
4. Sometimes health care providers make me wonder if their diagnosis is correct.	1	2	3	4	5
5. I felt well supported during the processes of returning to school following concussion.	1	2	3	4	5
6. When I go for health care, the provider is careful to check everything when treating and examining me.	1	2	3	4	5
7. Returning to school following my concussion has been easy.	1	2	3	4	5
8. Returning to sports following my concussion has been easy.	1	2	3	4	5
9. I am performing as well in my sport now as I was before my concussion.	1	2	3	4	5
10. Health care providers provided me with all information that I needed to know.	1	2	3	4	5
11. Overall, I feel as good now as I did before the concussion.	1	2	3	4	5
12. Those who provide my health care sometimes hurry too much when they treat me.	1	2	3	4	5
13. Health care providers sometimes ignore what I tell them.	1	2	3	4	5
14. I have some doubts about the ability of the health care providers who treat me.	1	2	3	4	5
15. Health care providers usually spend plenty of time with me.	1	2	3	4	5
16. I am performing as well in school now as I was before my concussion.	1	2	3	4	5
17. I am dissatisfied with some things about the health care I receive.	1	2	3	4	5
18. I felt well supported during the processes of returning to sports following my concussion.	1	2	3	4	5

If on a normal day before your concussion, you felt 100%, right now you feel _________% in terms of overall functioning.
If you do not feel 100% in terms of overall functioning, why not?

APPENDIX I: PATIENT SATISFACTION SURVEY SCORING

Patient Satisfaction Survey-
Adapted from the Short-Form Patient Satisfaction Questionnaire (PSQ-18)

Scoring

Subscale	**Average of the following items:**
General Satisfaction	3, 17
Technical Quality	2, 4, 6, 14
Communication	1, 13
Time Spent with Doctor	12, 15
Support for Returning to Activities	5, 7, 8, 9, 10, 11, 16, 18
Total	**Average of all items**

Scoring of individual items

Numbers	Original Response Value	Scored Value
1,2,3, 5, 6, 7, 8, 9, 10, 11, 15, 16, 18	1 2 3 4 5	5 4 3 2 1
4, 12, 13, 14, 17	5 4 3 2 1	1 2 3 4 5

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