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Policy Recommendations for Concussion Recovery: Using Evidence Based Data for a Safe Return to Learn in Student-Athletes

by

Maya Vanderhorst

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Science, Technology, and Public Policy

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Abstract

The return of concussed students and student-athletes to the classroom is commonly referred to as return-to-learn (RTL). RTL, however, is often overshadowed by returning a student-athlete back to athletic competition (return-to-play), with few recommendations and studies evaluating the effect of improper management of recovery from a concussion in an academic setting. Therefore, the research proposed here aims to track how symptom severity, student behaviors, and oculomotor performance formulate our ability to prognosticate how a student will respond to academic stimuli post-injury. This will be achieved by longitudinally tracking student-athletes as they recover from concussion, using a repeated measures design to sample data. The data was analyzed using an analysis of variance mixed effects model to understand the relationship between daily behaviors and symptom prevalence. The study identified overall time, caffeine intake, alcohol consumption, screen time, music listened to, physical activity, sleep duration, step count, and gender as significant factors associated with concussion symptom recovery and classroom management. Linear regression was utilized to correlate RTL recovery time to oculomotor scores, to preliminarily show how these scores can inform medical personnel when a student can return, unrestricted, to the classroom, and the types of accommodations to suggest for use in the classroom during recovery. Additionally, the Rochester Institute of Technology was used as a case analysis of current RTL procedures (athletic and academic management) to find areas of inefficiencies in providing timely and sufficient support to concussed students. The data collected and presented in this study was utilized to develop preliminary, evidence-based RTL guidelines to provide clinicians, athletic training staff, and university stakeholders with policies and practices to better ensure proper care is taken among students recovering from a concussion.

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Definition
ADAAA	Americans with Disabilities Act Amendments Act
AF	Accommodative Facility
ANOVA	Analysis of Variance
AT	Athletic Trainer
BCTT	Buffalo Concussion Treadmill Test
BDNF	Brain-derived Neurotrophic Factor
CDC	Centers for Disease Control
CISG	Concussion in Sport Group
DSO	Disabilities Services Office
fMRI	Functional Magnetic Resonance Imaging
HIPAA	Health Insurance Portability and Accountability Act of 1996
HR	Heart Rate
Hx	History
IDEA	Individuals with Disabilities Education Act
IEP	Individualized Education Program
IMPACT	Immediate Post Concussion Assessment and Cognitive Testing
KD	King Devick
mTBI	Mild Traumatic Brain Injury (Concussion)
NCAA	National Collegiate Athletic Association
NCBI	National Collaborative on Children's Brain Injury
NPC	Near Point of Convergence
RIT	Rochester Institute of Technology
RTL	Return to Learn
RTP (RTS)	Return to Play (Sport)
SAC	Standard Assessment of Concussion
SCAT5	Sport Concussion Assessment Tool 5

1. Introduction

1.1 Background: The Silent Epidemic

According to the Centers for Disease Control and Prevention (CDC), a traumatic brain injury is an important public health problem in the United States.[1] Frequently referred to as the *silent epidemic*, complications from a traumatic brain injury (TBI) can lead to changes that affect cognitive, behavioral, and emotional function.[1] The Concussion in Sport Group (CISG) defines a concussion, or a mild traumatic brain injury (mTBI) as a "direct blow to the head, face, neck, or elsewhere on the body that causes the brain to move rapidly back and forth or twist within the skull".[2] As defined, this biomechanically induced trauma causes the neurons in the brain to become damaged, affecting brain structure and function. Damage to these cells results in an energy deficit and decreased blood flow to the brain resulting in decreased function.[3] As a result, individuals with mTBI experience a variety of symptoms that can affect four domains of functionality, summarized in Table 1.[4,5]

Table 1. Summary of Signs and Symptoms That Can Arise in an Individual Who Suffered From a Concussion

Physical (Somatic)	**Cognitive**	**Emotional**	**Sleep**
• Headache • Fuzzy or Blurry Vision • Dizziness • Fatigue • Drowsiness • Sensitivity to Light • Sensitivity to Noise • Balance Problems • Nausea or Vomiting	• Difficulty Thinking Clearly (Foggy) • Feeling Slowed Down • Difficulty Concentration • Difficulty Remembering New Information	• Irritability • Sadness • Feeling More Emotional • Nervousness or Anxiety	• Sleeping More than Usual • Sleeping Less Than Usual • Trouble Falling Asleep

With an estimated 3.8 million recreation and sport related mTBIs that occur annually in the US, sport related concussions are the second most common cause of mTBI for those aged 15 to 24, just behind motor vehicle crashes.[6] A 2019 study by Breck et al. found a prevalence of 132.4 concussions per 10,000 (1.32%) students over a 9-month academic year among undergraduate students (including varsity athletes).[7] Compared to the incidence rate of 981.9 concussions per 100,000 (0.98%) people in 2010, among a similar age group (9-22), the rise in cases is concerning, especially among a population of individuals who are placed in a setting requiring high functionality of the brain.[7] The increase in incidence of concussion can likely be attributed to the evolution of concussion policy, and the changing laws that require the injury to be diagnosed and treated by medical personnel who are present at practices and games. Furthermore, improving education around concussion and its effects also contributes to injury recognition and incidence, as more athletes, coaches, and parents are aware of the signs and symptoms. Finally, as more youth are participating in sport, incidence rates also increase.

Studies have shown that removal from play, school, or work are the most important aspects of acute management, allowing for sufficient rest, and ensuring the brain can restore proper blood flow.[8] However, the challenge with concussion management is that concussions are non-specific and often present heterogeneously. Additionally, symptoms may develop rapidly or can be delayed in onset, hours to days after the initial injury, making it difficult to diagnose a concussion and remove an individual from harmful stimuli.[9] For these reasons, concussions are one of the most complex injuries faced by clinicians, who play an integral role in post injury management.[10]

1.2 Sport-Related Concussion Policy

It wasn't until the late 1970s and 80s that concussion prevalence began to become a concern among American football players, when data from neuroscientists sparked a desire to learn more about concussion in sport and the negative effects they have on brain function. In recent years, a growing understanding of concussion and its detrimental effects has caused this trauma to emerge at the forefront of sports conversation and research.[11] In the early 2000's, work from Bennett Omalu and Anne McKee showcased the tau deposits found in deceased American football professionals, highlighting the cause-and-effect relationship between hits to the head and altered brain health. However, despite this novel work, concussion management policies and protocols lacked; that is until 2006.

Concussion management changed forever in 2006, after a thirteen-year-old football player in the state of Washington suffered significant trauma during play. Zackery Lystedt was playing in a middle school football game when he was tackled by an opposing player, causing his head to hit the ground. He was removed from the game with a severe headache, but later returned to play in the second half. As a result, Zackery collapsed on the field, and was rushed by ambulance to the hospital, where he underwent an emergency craniectomy, a neurosurgical procedure to alleviate the swelling of his brain. The injury caused several neurological deficits, including the inability to stand independently, delayed speech, impaired swallowing, and partial paralysis.[9] Upset by the improper evaluation and treatment following his injury, Zackery's parents worked with the Washington State Congress and CDC to enact a bill that would prevent similar injuries among youth athletes. The Zackery Lystedt Law was passed in the state of Washington, requiring all student-athletes to be removed from sport when a head injury is suspected.[12] Furthermore, an athlete would only be able to return to play after receiving written clearance from a medical professional. Sparked by the work of the Lystedt family, and the resulting body of research in the field of concussion management practices, organizations like the National Collegiate Athletic Association (NCAA), the Concussion in Sport Group (CISG), and professional sport leagues adopted similar concussion protocols and policies, known commonly as return to play (RTP).[9]

The RTP protocol, being well received, was adopted by the NCAA, Pop Warner, professional sports leagues like Major League Baseball, the National Basketball Association, and the National Football League, and even found its way into state legislation across all 50 United States. The protocol is built around a stepwise reintegration back to unrestricted physical activity. The progression begins with activity around daily living, moving next to light aerobic exercise, and then to sport specific activities. See Table 2 for full details.[2] In order to progress through the RTP protocol, the athlete, who is monitored daily, must not have a relapse in signs or symptoms. The RTP protocol was an important step in reducing the risk of secondary impact syndrome and persistent post-concussive symptoms, resulting from premature engagement in physical activity.[13]

Table 2. Return to Play Protocol[2]

Table 1 Graduated return-to-sport (RTS) strategy

Stage	Aim	Activity	Goal of each step
1	Symptom-limited activity	Daily activities that do not provoke symptoms	Gradual reintroduction of work/school activities
2	Light aerobic exercise	Walking or stationary cycling at slow to medium pace. No resistance training	Increase heart rate
3	Sport-specific exercise	Running or skating drills. No head impact activities	Add movement
4	Non-contact training drills	Harder training drills, eg, passing drills. May start progressive resistance training	Exercise, coordination and increased thinking
5	Full contact practice	Following medical clearance, participate in normal training activities	Restore confidence and assess functional skills by coaching staff
6	Return to sport	Normal game play	

NOTE: An initial period of 24–48 hours of both relative physical rest and cognitive rest is recommended before beginning the RTS progression.
There should be at least 24 hours (or longer) for each step of the progression. If any symptoms worsen during exercise, the athlete should go back to the previous step.
Resistance training should be added only in the later stages (stage 3 or 4 at the earliest). If symptoms are persistent (eg, more than 10–14 days in adults or more than 1 month in children), the athlete should be referred to a healthcare professional who is an expert in the management of concussion.

Since 2014, after various lawsuits surrounding alleged standard of care misconduct, the NCAA further expanded its policy on concussion recovery and RTP.[14] The policy now mandates no same-day RTP for an athlete diagnosed with a concussion and requires clearance by a physician before return to sport. Adjustments also include a return to baseline for neuropsychological testing (eye function, coordination, balance, etc.), symptom monitoring, and the presence of medical personnel with training on the diagnosis, treatment, and management of concussions at all contact-sport games and practices.[14] Today, best practices for clinical professionals include comprehensive documentation of symptom severity, protocol progression, and other functional aspects of the athlete’s recovery such as cognitive and physical rest, vestibular and oculomotor rehabilitation exercises, and gradual integration of physical and cognitive activity – symptom limited.[15]

As awareness towards proper management of sports related concussion increases, Athletic Trainers (AT) and other medical professionals have developed a better understanding of the risks associated with rushing recovery in student-athletes.[16] A widely accepted recommendation is proper rest until symptoms resolve, followed by the RTP progression. Physical and cognitive exertion are emphasized as activities that require concentration and attention that may exacerbate symptoms if not dosed properly. As the necessity for proper management continues, literature is now directing its focus to the challenges student-athletes face in their academic lives, preliminarily suggesting the need for limited or adapted scholarly activities while symptoms persist. The return of concussed students and student-athletes to the classroom is commonly referred to as return-to-learn (RTL). RTL, however, is often overshadowed by returning a student-athlete back to athletic competition (RTP), with few recommendations and studies evaluating the effects of improper management of recovery from a concussion in an academic setting.[17]

1.3 Research Questions

As uncovered by several researchers[6,17–21], RTL guidelines for students in higher education lack the proper awareness and support from university stakeholders. Sequelae following brain injury infringe upon the student’s ability to succeed on academic tasks. Meanwhile, accommodations and procedures for managing these challenges are vague and often difficult to obtain, presenting the need for methods of improving RTL recommendations.

This thesis aims to track how symptom severity, student behaviors, and oculomotor performance formulate our ability to prognosticate how a student will respond to academic stimuli post-injury. The goal of this research is to answer the following questions:

1. Can longitudinal behavioral and symptom data produce an evidence-based set of RTL recommendations?
2. Can oculomotor performance post-concussion prognosticate RTL readiness?
3. To what degree does RIT follow current RTL recommendations?

This will be achieved by longitudinally tracking student-athletes as they recover from concussion, using a repeated measures design to sample data. The data collected here will ideally provide clinicians, athletic training staff, and university stakeholders with empirical evidence to develop a plan for RTL. Optimistically, the data presented in this thesis will corroborate earlier findings among the collegiate population and begin improving recommendations and policies for national and global groups (i.e., National Collegiate Athletic Association, National Athletic Trainers' Association, Concussion in Sport Group). Additionally, the Rochester Institute of Technology will be used as a case analysis of current RTL procedures (athletic and academic management) to find areas of inefficiencies in providing timely and sufficient support to concussed students. This study will optimistically be used to outline where the current RTL paths fail and provide direction and recommendations among all universities.

1.4 Motivation for Thesis

Studies have shown that removal from play, school, or work are the most important aspects of initial management, allowing for sufficient rest, and ensuring the brain can recover. Premature integration into strenuous cognitive or physical activity can lead to long term functional impairments of individuals suffering from a concussion.[17] While research has provided consensus on the proper return-to-play process[2], advice for returning the athlete back to the classroom is often vague and overshadowed by the goal of returning the athlete back to the field.[17] RTL parallels return-to-play in that it suggests a gradual, individualized plan to guide students back to class;

however, it currently lacks sufficient data to suggest proper management and re-integration steps to prevent premature use of the brain during strenuous cognitive activity.[19]

Unlike concussions incurred by students in K-12, concussions in college students are not as flexibly managed. In collegiate settings, the responsibility of seeking accommodations falls to the student. Paired with an increased pressure to maintain and succeed academically, students can endure additional stress and fear around seeking accommodations that may cause them to fall behind their peers.[21] The lack of a designated point person for concussion management at universities means that proper medical-academic communication, correct accommodation selection, and necessary proof of injury is not yet streamlined.[20] Compounded with little education around the effects of a concussion in the classroom, proper management of a student's RTL progress lacks sufficient evidence, education, and support.

2. Literature Review

2.1 Current State of Return to Learn

Over the past few years, management of concussions in school-aged individuals has been centered around proper re-integration to athletics, as well as the classroom.[19] According to the NCAA, "cognitive activities require brain energy utilization, and after a concussion brain energy may not be available to perform normal cognitive exertion and function".[22] RTL parallels RTP in that it suggests a gradual, individualized plan to guide students back to class; however, current RTL recommendations are often vague and overshadowed by RTP.[19] Current RTP protocols provide accurate means to athletic recovery, coupling rest and gradual return to physical exertion as guided by monitoring of symptom prevalence and heart rate, over time. Furthermore, failure to implement cognitive rest in student-athletes, due to challenges from implementing a RTL protocol, can prolong recovery on both the academic and athletic side.

2.2 Return to Learn Evaluation

2.2.1 K-12

To date, only a handful of studies have evaluated the effects of re-integration into the classroom immediately following a concussion. The importance of a RTL protocol for students has been repeatedly addressed, however, many of these studies focus on adolescents (K-12) over students in a collegiate setting. From these studies, best practices slowly emerged into the field, both clinically and practically, however, contradictory opinions and data have resulted in a lack of consensus around academic outcomes, physician recommendations, length of recovery, symptom difficulties, and appropriate academic accommodations or guidelines.

2.2.1.1 Academic Outcome

One common theme among RTL research is academic outcome/performance in individuals diagnosed with a concussion compared to healthy (cognitively) control students. In 2015, Alexander et al. found that adolescents who were involved in non-contact sports, classified based on traditional low rates of concussion and small numbers of collisions or impacts to the ground, improved academically overtime while their counterparts who were involved in contact sports (rugby) declined or remained stagnant academically, independent of their concussion history.[23] The results of this study showcase the potential effects of subconcussive hits on cognitive function. A subconcussive hit is a hit to the head that does not result in any clinically observable signs or symptoms of a concussion, or in other words, a trained professional cannot detect or diagnose a concussion due to the absence of the common signs or symptoms. Although these hits cannot be diagnosed as a concussion, recent research by Bailes et al. has shown that these hits can still cause harm.[24] Functional magnetic resonance imaging (fMRI) from the Bailes' research study indicated that individuals who were FOI+ (positive for subconcussive hits), identified through performance on the neurocognitive IMPACT test, had reduced blood flow compared to healthy individuals. Although not as severe as those identified as COI+ (individuals diagnosed with a concussion), the FOI+ group still showed significant changes in blood flow, signifying the effect of trauma that occurs to neurons from subconcussive hits.[24]

Additional studies on academic outcome following a concussion found that students diagnosed with a concussion experience a greater level of academic dysfunction compared to peers with an extremity injury, especially among the female population and those diagnosed with multiple concussions. Furthermore, these students missed a greater number of school days than their peers with extremity injuries.[25] Finally, Wasserman et al. found 42% of concussed students received academic adjustments one week after their injury compared to 25% among students with an extremity injury.[25] Both of these studies suggest that students who participate in contact sports are more susceptible to academic issues and reduced academic performance following a concussion.[23,25]

A study by Ransom et al. showcased how concussions negatively impacted a student's perception and ability towards completing academic tasks, like studying and understanding class material, and can often lead to exacerbation of symptoms when returning to the classroom.[26] These researchers also found that students who were actively symptomatic, reported more academic related problems than those students who had recovered or were asymptomatic. Furthermore, greater severity of symptoms was associated with more academic problems and reduced skill, with 88% and 77% of symptomatic students reporting performance difficulty from symptom interference and decreased academic skill, respectively.[26] Finally, Ransom's findings discovered perception of academic task difficulty was age dependent, with a larger portion of high school students expressing concern on performance in class compared to their elementary and middle school peers.[26] Parallel studies suggest that concussion can slow a student's processing speed, affect memory, reduce attention span, and impair concentration, which can affect school performance, academic skill, and worsen symptoms like headache, dizziness, anxiety, and sensitivity to light.[27]

Additional studies on academic outcome by Corwin et al. found that older individuals who experience worsening symptoms during oculomotor exams were more prone to a decline in academic performance, with 61% of students reporting a decline in grades at their physician appointments.[28] Arbogast et al. also found that physicians noted 19% of students reported a decline in school performance at their first evaluation, and 30% at their follow-up appointments, suggesting those with persistent symptoms or prolonged recovery have greater academic problems.[29] Additionally, 38.5% of students reported experiencing more symptoms when they resumed academic activities, with difficulty concentrating being the largest complaint of returning to academic stimuli following a concussion.[30]

2.2.1.2 Physician Recommendations

Due to a lack of consistent findings on the effects of concussions on RTL, and the limited research in this field of concussion recovery compared to the RTP protocols, physician recommendations for concussion management prescriptions have also resulted in inconsistent findings. In fact, Stern et al., found that 35% of New England physicians reported an absence of clinical guidelines for RTL in their ED's while an additional 57% reported having guidelines in place but failed to use them consistently.[31]

One study by Gibson et al. found that 63% of patients diagnosed with a concussion received cognitive rest recommendations, with a higher percentage of prescription among youth under the age of 15 compared to those over the age 15.[32] A parallel study by Arbogast et al. discovered that 62% of pediatric primary care physicians endorsed giving patient recommendations for cognitive rest immediately following a concussion, however, only 11% of electronic medical records from initial visits, and 14% from follow-up visits, included written cognitive rest recommendations.[29] Furthermore, only 2% of prescriptions were written for school-specific rest and accommodation instruction to be provided to administrators.[29] A later study by Moor et al. in 2015, discovered that among their population of adolescent student athletes with sport related concussions, 100% of individuals received recommendations for physical rest (as required by the RTP protocol), while only 93% and 78% received recommendations for mental rest from electronics and cognitive rest (including restrictions from school), respectively.[33] However, Moor et al. also found that higher levels of adherence to recommended physical and cognitive rest resulted in slower recovery time than those who were less adherent to recommendations post-concussion.[33]

Recent work by Leddy et al. has shown that following a period of rest for 24-48 hours, exercise or training can be good for the brain, and may aid in recovery, to help overcome the intolerance to exercise as a result of autonomic dysfunction (inability to exercise due to symptom prevalence).[34–36] To identify this dysregulation, Leddy and Willer developed the Buffalo Concussion Treadmill Test (BCTT), which determines the symptom-exacerbation exercise threshold of concussed patients. This symptom threshold corresponds to the patient's heart rate and is used to determine the proper dose of aerobic exercise to correct the dysregulation and speed up recovery. Leddy et al. showcased that when exercise is dosed properly, the brain can respond positively by producing brain derived neurotrophic factor (BDNF), a growth hormone for the brain that can assist in neuroplasticity by making neurons more viable. This growth factor has been shown to improve cognitive function, showcasing that exercise is medicine.[34] In a mixed effects linear model, the data suggests that the BCTT does not significantly affect symptom reporting or delay recovery by increasing symptoms, further proving that the use of the BCTT following a concussion to be safe. The authors also found that heart rate (HR) is significantly associated ($R^2 = 0.3$) with days to recovery, indicating that every 1 bpm increase in HR resulted in a 0.82-day shorter recovery period. The authors also showcased that subjects with a low HR threshold, and greater exercise intolerance (<135 bpm determined using k-means) are about 45 times more likely to have a prolonged recovery.[35] The results from this study corroborate the findings from Moor et al. that the traditional approach of cocoon therapy (physical rest until symptoms resolve) may not be the best recommendations for recovery.[33]

Other studies by Corwin et al. and Brown et al. outline inconsistent findings on the use of cognitive rest and the correlation to symptom resolution; one found that rest increased length of recovery while the other found that those who engage in cognitive activity without restrictions (accommodations) had longer time to recovery (symptom resolution), respectively.[28,37] These findings further the need for more evidence-based data that physicians can use to improve RTL guidelines similar to the advancements made in RTP, before a consensus could be reached for proper RTL guidelines.

2.2.1.3 Length of Recovery

A large limitation in RTL research surrounds the minimal number of studies regarding the average time to fully recover and return to the classroom without any difficulty to perform academic tasks. A study by Carson et al. found that 44.7% of students returned to school prematurely, documented through RTL recovery time and accompanying symptoms.[17] In other words, students who returned to full academic stimuli without the support of accommodations, who still experienced symptoms were designated as returning prematurely. Corwin et al. found that in a sample of concussed youth, the average time to return to school part-time was twelve days, while time to return to school full-time without accommodation was thirty-five days.[28] This study also found that 73% of students were symptomatic for greater than four weeks, 73% were prescribed some form of accommodation, and 61% reported a decline in grades. This data also suggested it took longer for younger children to fully recover than their older counterpart, with academic accommodations provided most of the time to these older students.[28] Grubenhoff et al. found that children with persistent symptoms miss a greater number of school days, yet still returned to school within thirty days of the injury, likely contributing to the further persistence of the symptoms.[38] Recent studies implementing evidence-based data on length to recovery have found that those who demonstrated worse symptoms during oculomotor exams required more time to return to school full time (74 vs. 22 days).[28] These researchers also found that adolescents who experience multiple concussions throughout their lifetime showed poorer outcomes; individuals with three or more prior concussions took 3.6 times longer to fully RTL than those with no prior concussions.[28] Millichap also found that concussed students with initial vestibular clinical signs/scores also took significantly longer to RTL than those without (59 vs. 6 days).[39]

2.2.1.4 Symptom-Related Concussion Difficulties

The challenge with concussion management is that concussions are non-specific and often present in various forms; not all individuals experience the same symptoms while some symptom domains may be worse than others. Symptoms may develop rapidly or can be delayed in onset, hours to days after the initial injury.[9] Concussion symptoms are often subtle, with loss of consciousness occurring in only a minority of cases. Additionally, there is no proven measurable indicator based on imaging or blood tests for TBIs that do not result in skull fractures or other bodily injuries, which typically do not present in sport related concussions.[9] Instead mTBI diagnosis relies on proper knowledge of symptoms by a medical professional and available baseline metrics in eye tracking, balance, and symptom severity. For these reasons, concussions are one of the most complex injuries faced by sports medicine professionals and other clinicians who play an integral role in postinjury management.[10] These challenges can make it difficult to identify when a student has suffered from a concussion and can often result in a return to the classroom without the appropriate support or guidance.

Carson et al. estimates that 45% of youth return to the classroom, unrestricted, before they are asymptomatic, resulting in further cognitive, behavioral, academic, and/or emotional problems.[17] Furthermore, studies by Baker et al. and Darling et al. found that 38% and 38.5% of students reported the onset of new challenges and symptoms upon returning to the classroom post-concussion, respectfully.[30,40] Ransom et al. found that these cognitive, physical, and emotional symptoms contribute to a decline in grades and an increase in concern among adolescents, which often leads to pressures of not falling behind among peers, resulting in premature RTL.[26] Iadevaia et al. also found that effects of symptoms, feelings of frustration, school attendance, and the nature of interpersonal and team relationships were indicated as factors that negatively contributed to a concussed adolescents' quality of life.[41] They discovered that the physical symptoms experienced post-concussion were the most distressing challenge, leading to significant impacts on their emotional and academic functioning.[41] In addition to the impact of symptoms on academic performance and emotional regulation, Stein et al. discovered that 56% of concussed students cited the loss of school, sport-related activities, and social interaction as the worst part of their concussion.[42]

2.2.1.5 Academic Accommodations and Guidelines

Despite literature suggesting the correlation of poor academic performance following a concussion without proper management of gradual re-integration strategies, the lack of sufficient evidence and communication between educational and medical staff can lead to students being forced to meet educational demands without accommodation for cognitive deficits associated with concussions.[17] Until 2020, when a consensus statement was reached, conflicting evidence made it difficult for primary and secondary school teachers and administrators to be prepared to support adolescents upon RTL.[43] During the 2010's, it was estimated that between 47% and 70% of schools lacked formal guidelines to assist adolescents during RTL[13], while state laws in all 50 states required districts to implement a RTP protocol by 2014.[9] Furthermore, the review by O'Neill et al. suggested that between 40% and 73% of students require accommodations once they return to the classroom following a concussion.[13] Common academic accommodations include things like extended time on assignments/exams, reduced workload, more breaks, wearing sunglasses or headphones in the classroom, excused absences, or assigned notetakers.

One of the largest contributing factors to the implementation of accommodations or RTL guidelines surrounded education and training.[13] Glang et al. found that students from schools that offered intervention programs were more likely to receive accommodations like extended time on assignments and reduced workload.[44] The intervention program consisted of training in sports concussion for each member of the school community, guidelines on creating a concussion management team, and strategies to support students upon RTL.[44] According to a study conducted by Dreer et al., 41.9% of teachers reported their school provided concussion information to them, however, only 12.4% reported they considered themselves “very knowledgeable” regarding concussions and their effects on students.[45] Hachem et al. discovered that of the 85% of schools that offered concussion education to staff, the training was primarily geared toward athletic personnel.[46] Furthermore, only 53.8% and 43.6% of these schools provided concussion education to student athletes and parents, respectfully.[46] From an administrative standpoint, only 37.2% of principals reported having some form of concussion education in a study conducted by Heyer in 2015. Researchers found that those who completed the training were more likely to provide or support further training to teachers and educational staff.[47]

In addition to principals, schools nurses and athletic trainers (AT) were identified as the most integral providers during RTL. According to Kasamatsu et al., the strongest predictor of a school system having a robust RTL policy in place was frequent communication between educational and medical staff.[48] However, school nurses still identified challenges around communication with the medical professional who diagnosed the injury and the rest of the academic rehabilitation team around consensus and best practices.

Changes to academic legal guidance have also provided K-12 students with many layers of protection in the classroom after a concussion. Recent changes (2016) to the Americans with Disabilities Act Amendment Act (ADAAA) introduced concussion as a recognized disability, guaranteeing 504 accommodations to anyone with this disability.[49] Working in parallel with the ADAAA, the Individuals with Disabilities Education Act (IDEA) assures students an appropriate educational experience, supporting student success. IDEA provides all students with a free, fair, and equitable education, closing all educational achievement gaps related to disability. Implementation of accommodations guaranteed under these federal laws are carried out by the K-12 educator. Educator evaluations are based on the ability of students to reach “student learning outcomes” and be successful within the classroom. These circumstances could motivate educators to proactively monitor and initiate accommodations to students who are underperforming due to concussion sequelae, even without the 504 plan or Individualized Education Program (IEP), provided the knowledge they have on the learning effects from a concussion.[50] The nature of IDEA supports the educator’s choice to initiate or advocate for academic accommodations for a student (even if they have not been formally diagnosed to ensure the student can succeed in the classroom).

2.2.1.6 Reaching a Consensus in K-12 RTL Management

After a 2011 Nittany Summit on Childhood Brain Injury, professionals developed general recommendations for building statewide school capacity to support students with all severities of acquired brain injuries. These experts later formed the National Collaborative on Children’s Brain Injury (NCBI) to work in this field of TBI management. This group is focused on improving school-related acquired brain injury support and services, and in 2016 created a NCBI Return to Learn workgroup for focus on guidance to schools when supporting students post-concussion. Tasked with gathering representative opinions on the essential elements of RTL, the group formed the first national concussion RTL consensus.[43] At the 2016 NCBI Return to Learn meeting, the professionals utilized a Delphi process to reach consensus on thirteen themes of RTL,

Appendix A. Within these themes/recommendations, there are six overarching categories: Cognitive Rest, Concussion Management Team Composition, Progress Monitoring, Ascending Levels of Academic Support, Neuropsychological Testing, and RTL Legislation.[43]

According to McAvoy et al., empirical evidence has suggested a two-day period of rest followed by a gradual return to activity, where a progressive RTL process has demonstrated clinical utility.[43] Additionally, the consensus aligns with literature suggesting the use of an individualized plan cannot be pre-determined and should be dependent on symptom severity and prevalence at the time of injury.[43] The NCBI committee has also pointed to the role of concussion education in proper RTL management. The professionals argue parent education plays an important role in empowerment to advocate for their child, paired with relevant input from a healthcare provider. In addition to parent education, the Delphi consensus stresses the importance of educator training on concussion strategies and recognition of symptom presentation, to support students throughout this progressive recovery.[43] Furthermore, the Delphi consensus recognizes that proper RTL management is centered around an interdisciplinary team composed of representation from the student, parents, coaches, nurses, athletic trainers, psychologists, school counselors, teachers, administrators, student support service members, and health care providers.[43] Communication among these members is imperative to proper RTL management and should be overseen by a point person within the school based academic team to ensure collaboration between the student, health care providers, parents, teachers, and coaches.

The Delphi participants suggest regular symptom and academic monitoring by school professionals during recovery, to ensure proper measures of accommodation are being taken. The committee also recognizes and supports the use of informal (teacher-initiated accommodations) and formal (504 plans and IEPs) support provided by teachers and administrators. The consensus findings also indicate neuropsychological exams as helpful in development of individualized RTL plans to determine appropriate accommodations and support services that may be needed.[43]

Finally, the Delphi consensus committee recognizes the benefits of enacting RTL legislation, which include increased awareness of concussion and resulting learning impacts among educators, improved communication among the interdisciplinary team, and higher accountability for RTL academic supports.[43] Since the identification of these themes, more professionals have begun to adopt strategies for RTL, with many K-12 districts adopting a RTL protocol similar to that developed for RTP. However, a lack of empirical data surrounding these practices within the RTL protocol, legal support for their implementation is still yet to be adopted.[13]

2.2.2 Collegiate

While consensus around K-12 RTL management has begun, collegiate RTL has lacked initiation. The challenges of RTL have been recognized as an important factor for students, with literature suggesting older students had significantly more academic-related problems, diminished skill, and increased concern about academic repercussions of their injury compared to younger adolescents.[26,51] Furthermore, pre-mature integration in both cognitive load and school attendance, paired with premature integration into physical activity, were seen to exacerbate symptoms.[19] These findings suggest a relationship between higher levels of academia and increased difficulties post-concussion. The extent of this link, however, lacks evidence-based support since most RTL research has produced minimal findings beyond high school students.

2.2.2.1 Existing Data

A pilot study conducted by Bevilacqua et al. in 2019, was the first of its kind to provide preliminary evidence-based recommendations for managing collegiate RTL, and to expand on earlier findings among the adolescent population.[18] Nine full time college students diagnosed with a concussion were monitored throughout recovery. The study utilized a repeated measures design, sending text messages four times a day to collect symptom severity data (headache, dizziness, difficulty concentrating, fatigue, and anxiety). The use of the four daily text messages was a novel approach, compared to cross-sectional symptom monitoring used once daily in other concussion investigations. Students were also contacted daily to obtain information on behaviors and habits, including fluid intake, physical activity, and class attendance.[18]

This study found that longer sleep duration, water intake, and overall time since injury to be beneficial factors in symptom recovery. Sleep duration was a significant factor in improving dizziness indicating a 0.06% reduction in symptom severity per minute of sleep. Water intake was associated with reduced anxiety, indicating with each 8oz serving of water consumed throughout recovery, anxiety severity reduced by 17%. Finally, time per hour was a beneficial factor in reducing symptomology in headache, dizziness, fatigue, anxiety, and difficulty concentrating, with estimate values between -0.0014 and -0.0041.[18] This study also showed two adverse factors for concussion symptom recovery. Longer duration of music listened to, and the absence of physical activity were shown to exacerbate symptoms. Time listening to music had a significant effect in increasing headache, difficulty concentrating and fatigue, with every minute of music increasing symptoms by 0.9, 0.81, and 0.72%, respectively. Physical activity, determined in a binary fashion (i.e., participated or did not), showed that the absence of physical activity was associated with increased symptoms of difficulty concentrating and fatigue. The other symptoms also saw adverse effects in the absence of physical activity, although not statistically significant.[18]

Complimentary survey results from this study found that 33 and 44% of participants in this study expressed concerns and difficulty with math and computer use during recovery, respectively.

These results corroborate findings from Ransom et al. on the difficulty of math and computer-based classes among a younger population.[26] Furthermore, 66, 56, and 33% of participants identified additional time on assignments/exams, reducing screen brightness, and wearing sunglasses in class were helpful accommodations during their re-integration into the classroom. In addition, 66% of participants reported that rest/sleep was most beneficial to their recovery, while 44% reported taking break from screens, class, and homework were helpful accommodations in the classroom.[18] This data begins to suggest accommodations that are most beneficial for certain class types as well as overall recovery, from the perspective of the individual experiencing the injury.

2.2.2.2 Collegiate RTL Perceptions

2.2.2.2.1 Students

Childers and Hux found college students who suffered from a concussion can face ongoing challenges in the classroom.[21] They discovered patterns of changes in cognitive, physical, and social/emotional effects which included 1) academic tasks often take longer to complete due to difficulty concentrating, 2) reduced memory, 3) vision changes, 4) reduced sleep, 5) fatigue, and 6) increased anxiety.[21] These corroborate findings identified in the K-12 literature. Their study reported that these students saw increased anxiety upon asking for academic accommodations, as it was challenging to communicate with professors, and felt it put them further behind peers. Furthermore, advocacy behind academic support lacked proper communication and knowledge around the effects a concussion truly had on them. Students were often not properly informed on the challenges they would face from the concussion and the accommodations that would be most beneficial to their performance.[21] Bowman et al. similarly suggests that student-athletes tend to face anxiety about needing accommodations, arising from increased pressure to not fall behind.[20]

There is also increased difficulty at the college level in getting professors to understand the needs of a concussed student, and the impact their injury has on academic performance when unsupported.[20]

2.2.2.2.2 Educators

When a student suffers a concussion, they are often referred to the university's disability services office (DSO) for assistance; yet these entities manage high volumes of requests, resulting in a similar timeline between the process of receiving necessary accommodations for the classroom and the typical recovery period of adult concussions (i.e., < 14 days). Additionally, Bevilacqua et al. (2021) discovered how, without medical verification of a concussion (i.e., doctor's note), students will face challenges in garnering assistance from their instructors.[19] In fact, three themes emerged from the Bevilacqua data: 1) awareness-external knowledge of concussion and previous experiences, 2) legitimacy-medical note provided or not, and 3) student accommodations-instructor's role and feasibility of accommodation.

The first theme, awareness, refers to the instructor's exposure to concussion. This study found that external knowledge or previous concussion experience did not appear to influence response to management in the classroom, which contrasts previous research expressing the importance of education on concussion[19]; however, it does support the theory from Mokris et al., that awareness of concussion is higher in faculty who have previously provided accommodations versus those who have not.[52] The second theme of legitimacy uncovered an important variable in the management of RTL. If no note was provided to the instructor or the DSO indicating an injury from a medical provider, factors like class size, student classification, and instructor empathy to award accommodations were identified by educators as variables that affected accommodation awards. The study found that the instructor's empathy played the largest role in awarding accommodations with no note. Instructors also expressed a greater deal of trust in graduate students over their undergraduate counterparts, based on their assumed "professional" status. Lastly, smaller classes allowed instructors the greater ability to build relationships with students, causing them to be more open (empathetic) to awarding accommodations when proof of injury was unavailable.[19] The final theme centered around the role within providing accommodations and the act of doing so. This study found that 70% of instructors currently believe they were part of the universities' RTL team however, 95% of instructors believe they should be part of the team. When asked further what role they should have, the consistent response was a peripheral role, in order to help the student be successful but not make the decisions on what to do.[19] Furthermore, instructors perceived that wearing sunglasses in class and excused absence from exams were the most and least feasible accommodation requests, respectively. This is likely due to the role in which professors play in these accommodations; sunglasses do not require the professor to change anything or alter the integrity of the class, while exemption from exams does not allow demonstration of knowledge acquired and would result in an alternative means of evaluating a student, requiring more time on the educators part. A common component regarding accommodations surrounded the time required for the professor to put forth to apply that accommodation and deal with any necessary changes or knowledge/capability of doing so.

2.2.2.3 Legal Guidance

Analogous to medical notes is the federal law ensuring assistance for those students who suffer from a disability. While concussion is recognized as a disability, the ADAAA only guarantees those with concussion at the university level the "opportunity to be successful".[53] This differs from K-12 education, which guarantees success. This is because of limitations in IDEA, which only pertains to educational environments that are "free and appropriate". College education, being neither free nor minimally appropriate, falls outside of this umbrella, creating a mismatched level of federal assistance. Additionally, limitations in this legislation are seen as Section 504 assistance is only provided after a university's disability office has received the appropriate documentation and approved the student's request for assistance. Eligibility, unfortunately, stems from acquiring a medical note, and understanding the assistance that is available them.

2.3 RTL Limitations and Challenges

Barriers like health insurance, time, and knowledge of available resources make it challenging for a student to obtain a doctor's note, legitimizing their concussion. When students don't know an MD note is required to receive 504, can't afford to see a doctor, or don't know that concussion falls under disability assistance, proper care cannot be taken for their injury.

Limitations among legal support for concussion within the university population centers around barriers faced in the assistances available to adult aged students as a result of HIPAA. No medical professional on the campus can share with other staff or educators the student's medical history unless approved by the student; a student is only provided with the contact and education on the resources that they could choose to pursue. However, the ability to get information on resources available to them requires them to be seen by a physician who can diagnose and guide the student through the process of recovery and assistance, who also has knowledge about university policies. Students who cannot afford to go to the doctor or do not have medical insurance are left to manage their injury on their own. Financial barriers can be high among the university student population who are living on their own for the first time and cannot afford to go to the doctor. Furthermore, injuries may occur outside of operation hours for the student health center and may result in delay of care when students do not have access to transportation to urgent care or emergency room centers.

One of the largest challenges around proper concussion management is centered around concussion education among students. When a student isn't aware of the changes in physical, cognitive, and emotional function, the injury can be misdiagnosed or result in no diagnosis at all.[6] Many authors suggest that the wide range of symptoms that can be experienced by an individual with a concussion, can cause concussions to go unnoticed and instead misinterpreted as other illnesses or diseases. They attribute this misinterpretation as a lack of proper education around the prevalence and duration of symptoms, the causes of a concussion, and how to recognize when it is important to seek care from a medical professional.[6] Better understanding of the safe post-concussion care reinforces the need for reducing the underreporting of concussions and the need for proper management both athletically and academically. Lack of knowledge around the effects of concussion on normal cognitive function can result in reduced academic performance, that may not be attributed to an injury and instead discourage the student on their ability to learn and be successful in the collegiate environment. Furthermore, undereducation around the resources available to students who have suffered from a concussion can result in delay of care, support, and increased symptomology. One can predict that many non-athlete students on a campus do not know the resources available to them to manage their concussion unless they are diagnosed or seen by a physician within the student health center and are referred to the DSO. As previously mentioned, limitations in health center hours, availability, and cost (insurance) could limit a student's ability to receive a diagnosis and further care.

Other challenges in implementing a RTL protocol, similar to RTP protocols, are centered around the variation in length of recovery and symptom prevalence and severity between individuals. The non-specific nature of concussions makes it challenging to provide specific advice for RTP and RTL in individuals and suggests the need for further research on how evidence-based data can suggest appropriate accommodations for student-athletes, as they progress through recovery.[17] Furthermore, many professionals suggest a student-athletes' performance in the classroom can predict when the brain has healed and is ready to return to full athletic competition, as symptoms during cognitive performance may take longer to heal over symptoms during physical activity.[51] This suggests that unrestricted integration back to sport should not occur until full integration back to the classroom is tolerated by the individual and could be a component addressed in future concussion protocols.[18]

Despite literature suggesting the correlation of poor academic performance following a concussion without proper management of gradual re-integration strategies, the lack of sufficient evidence and communication between educational and medical staff can lead to students being forced to meet educational demands without accommodation for cognitive deficits associated with concussions.[17]

3. Methods

The data collected in the study seeks to prognosticate the readiness of the injured student-athlete to return back to the classroom following a concussion by collecting observational data throughout recovery on symptomology, daily behaviors, and sleep/step data from an ActiGraph wristwatch. This observational study collects data from collegiate student-athletes over the course of their concussion recovery. This method, and data analysis, were originally piloted at Indiana University Bloomington[18]; therefore, this analysis will utilize an athlete sample at RIT to corroborate and expand upon the pilot findings, while simultaneously introducing the capacity of three oculomotor tests to prognosticate RTL readiness.

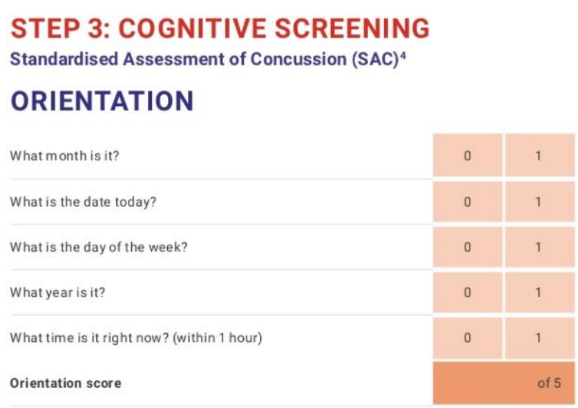
3.1 Participants

Longitudinal observational methods were utilized among the Rochester Institute of Technology (RIT) NCAA Division 3 (Division 1 Ice Hockey) student-athletes under the university Institutional Review Board (Human Subjects Research Office #02062821) approval. To be considered for the study, the student athlete must have obtained the concussive injury within seven days of being referred to the study and have been formally diagnosed with a mTBI (concussion). Additionally, the student must be enrolled as a full-time undergraduate (taking at least 12 credits) or graduate (taking at least 9 credits) student at the university and be between the ages of 18 and 28 years old.

3.2 Procedure

To be considered for the study, the student-athlete must first be diagnosed with a mild traumatic brain injury (concussion). Any injury more severe than a mTBI, like a skull fracture or a positive computerized tomography (CT) scan or magnetic resonance imaging (MRI) cannot be considered for the study. Participants in the study are diagnosed with a concussion by a member of the RIT Sports Medicine team (Athletic Trainer or Physician) using current concussion definitions[2] and SCAT5 diagnostic tools. Once a diagnosis is made the student will be referred to the Neurotrauma Lab. The lab member will reach out to the student to inform them of the study and set up a 30–45-minute appointment for study intake. During this intake appointment a lab member will meet the student in a private closed-door office. To begin, the study is briefly described, and instructions are given to the student to inform the researcher if they need a break during the meeting, to ensure their symptoms don't worsen.

To ensure the student is considered "able to consent" they must receive a perfect score (5/5) on the Standard Assessment of Concussion (SAC), which assesses orientation (Figure 1) in order to continue with the study. If the student-athlete does not score a 5/5 for the study, the student cannot be considered for the study.


STEP 3: COGNITIVE SCREENING
Standardised Assessment of Concussion (SAC)[4]
ORIENTATION

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

Figure 1. SAC Assessment to Determine Ability to Personally Consent to Study

Following the cognitive screening through the SAC, the researcher reviews the informed consent associated with the study. The informed consent contains information on the outline of what the longitudinal study consists of, identifies risks and benefits to the individual, confidentiality agreements, incentives, and the rights of the participant. Once reviewed, the student is asked to consent to the study. Within the informed consent the researcher evaluates the student-athletes to ensure they meet all inclusion criteria for the study. If one or more inclusion criteria is not met, or one or more exclusions are met, the student is not considered for the study. Refer to Table 3 for the inclusion and exclusion criteria for this study.

Table 3. Inclusion and Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
• Full-time student at RIT (undergraduate or graduate) • Diagnosed mild traumatic brain injury (concussion by a member of the RIT Sports Medicine team) • Between 18-28 years of age • Within 7 days post-injury	• Any head, neck, or face injury in the 6 months prior to the study (e.g., concussion, eye injury) other than the current injury • History of vestibular or ocular dysfunction or injury, other than those associated with concussion (e.g., vertigo, amblyopia or "lazy eye", orbital fracture, ruptured eardrum,) • Any neurological disorders (e.g., seizure disorders, closed head injuries with loss of consciousness greater than 15 minutes, CNS neoplasm, history of stroke) • Injury more severe than mild traumatic brain injury (skull fracture, positive CT or MRI) • Not able to personally consent (SAC) • Pregnant

Once consent agreements are signed, participants answer a series of questions regarding medical history and daily behaviors prior to the concussion. This demographic information is used to understand the date of the current injury, any confounding factors that may affect baseline symptom data, and to document baseline daily behaviors and academic course load. An outline of all the information gathered during intake for demographics and baseline data can be found in Table 4.

Table 4. Participant Demographics and Intake Data

Baseline Demographics Data	
Sex	Female : Male
Age	______ Years
BMI	____'____" Height, ______ lbs
Hx of Physician Treatment For:	
Migraines	No : Yes
Substance or Alcohol Abuse	No : Yes
Psychiatric Conditions	No : Yes
Sleep Disorder	No : Yes
Diagnosed with ADD/ADHD	No : Yes
Number of Previous Concussions	__________
Most Challenging Academic Aspects of Previous Concussions	____
Time of Current Injury	Morning : Afternoon : Evening
Location of Impact	Frontal : Parietal : Temporal : Occipital
Cause of Injury	Sport : Motor Vehicle Accident : Fight : Fall : Other
Pre-Injury Symptom Levels: (0 – 10)	
Headache	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Fatigue	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Dizziness	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Difficulty Concentrating	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Anxiety	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Sensitivity to Light	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Total Pre-Injury Symptom Score	__________
Pre-Injury Behaviors:	
Hours of Sleep per Night	__________
Minutes Listening to Music	__________
Minutes of Screen Time	__________
Caffeine Intake	Always : Often : Sometimes : Rarely : Never
Water Intake (8oz servings)	__________
Number of Credits Between 8-12pm	__________
Number of Credits Between 12-4pm	__________
Number of Credits Between 4-8pm	__________
Number of Credits Online	__________
Academic Major	__________
Undergraduate or Graduate	__________
Total Completed Semesters of College	__________
Any Current Academic Accommodations	__________

Following the collection of demographic and intake data, the participant is asked to complete three clinically validated oculomotor assessments to test eye movement and function. These tests are used to understand dysfunction in eye movement following the concussion and will be used to predict how a student will respond to academic stimuli. The participant is then provided with an ActiGraph wristwatch and instructed to wear the watch 24/7, except when showering to collect sleep and step count, daily.

Finally, the participant is informed on the daily procedure for providing symptom prevalence and daily behavior data to the research team. The participant's phone number is recorded by a member of the research team for collection of this data. Daily symptom prevalence is recorded through survey data via text messages. The participant is informed that they will receive four text messages a day and will be asked to report their symptom prevalence for headache, dizziness, difficulty concentrating, fatigue, anxiety, and sensitivity to light on a scale of 0-10 with 0 being none and 10 being the most severe. The participant is also informed on the questions that will be asked during a daily phone call regarding daily behaviors and class attendance.

This study is designed to longitudinally observe participants throughout their concussion recovery and is expected to last ≤ 4 weeks. At each two-week interval, the student will meet with a member of the lab to charge the ActiGraph watch, and ensure the participant is answering the text messages and phone calls properly. If the participant has not answered at least 80% of the phone calls and text messages, they will be excused from the study. Otherwise, they will continue on. Completion, or recovery, criteria is defined as a return to pre-injury (baseline) symptom levels for a 48h period while simultaneously attending classes without an increase in symptomology beyond baseline. Once recovered, the student will return the wristwatch, perform the clinical oculomotor tests, complete a 12-question Qualtrics survey on their recovery experience, and receive compensation.

3.3 Materials

Three clinical oculomotor tests are used to evaluate eye movement function: Near Point of Convergence (NPC), Accommodative Facility (AF), and King Devick (KD). The data collected from these assessments will be used to predict a student's recovery time and readiness to return to the classroom following a concussion. The data is collected twice throughout the study; once during intake and once when the student meets completion criteria and has returned to the classroom without an increase in symptomology.

The NPC tool assess the ability of the eyes to focus on a target as it moves closer to the face until binocular (both eyes) focus cannot be maintained (target is blurry or splits into two). This assessment taxes the small muscles that angle the eyes inward (towards the nose) and utilizes an accommodative ruler, marked in centimeters, to determine the distance from the face at which binocular focus can no longer be maintained. The test begins by placing the ruler underneath the participants nose and instructs the user to focus on the letter "T" on the target card on the ruler that is 20 cm from them. The researcher slowly slides the target card towards the participants eyes at a rate of 1-2 cm per second. The researcher slides the card until either 1) the researcher notices the eyes deviate away from the nose, or 2) the subject announces "stop" as a result of blurriness or the object splitting into two. The distance from the eyes on the ruler is recorded and repeated for a total of three times to obtain an average distance in centimeters.

The AF tool assesses the eyes' ability to re-establish focus as sight is transitioned back-and-forth between a near and far object, while reading off the letters on a character chart containing 10 columns and 10 rows. To assess this clinically, two of the same character charts (Hart Charts) are placed 40 cm and 5 m from the participant. The participant is then instructed to read the beginning four characters on the chart 40 cm away, then switch their sight to the 5 m chart and read the next four characters in the sequence. Participants are told to read as many four-letter combinations as they can, in this fashion (switching between the 40 cm and 5 m charts), in one minute. The more transitions one can complete, the better their AF. The column and row at which the subject reached at the end of one minute is recorded, as well as the number of errors that occurred.

Finally, the KD tool assesses the ability of the eyes to perform smooth left-to-right movement (saccades) while accurately and rapidly reading aloud randomized numbers. The test contains a single demonstration card and three test cards on a tablet software. The demonstration card is used to acclimate the participant to the test and asks them to read the numbers on the screen aloud as quickly and accurately as possible, in the same fashion they would read words off of a page (left to right, starting from the top and working down). The test cards are timed for speed and increase in difficulty through the elimination of guidance lines, and variations in spacing between the numbers. The tablet used in the study internally tracks the cumulative time for all three test cards. The timer starts when the participant touches the screen, revealing the next test card. The timer ends when they have finished reading the last number and touch the screen again. The cumulative time in seconds, and any errors, are recorded by the researcher. Refer to Figures 2-4 for an image of each test.

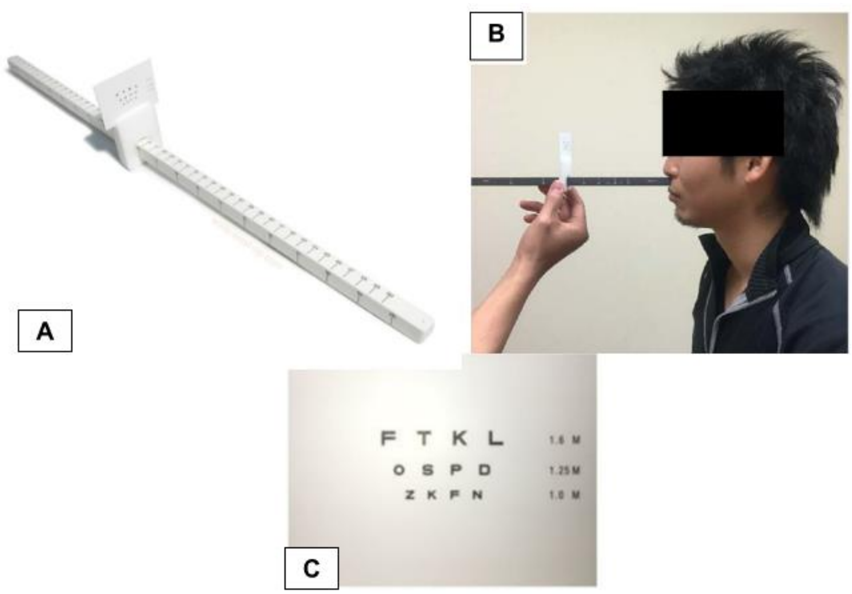


Figure 2. Near Point of Convergence Testing Materials and Set-Up

Note: A) Accommodative Ruler, B) Testing Setup and Procedure, and C) Target Card

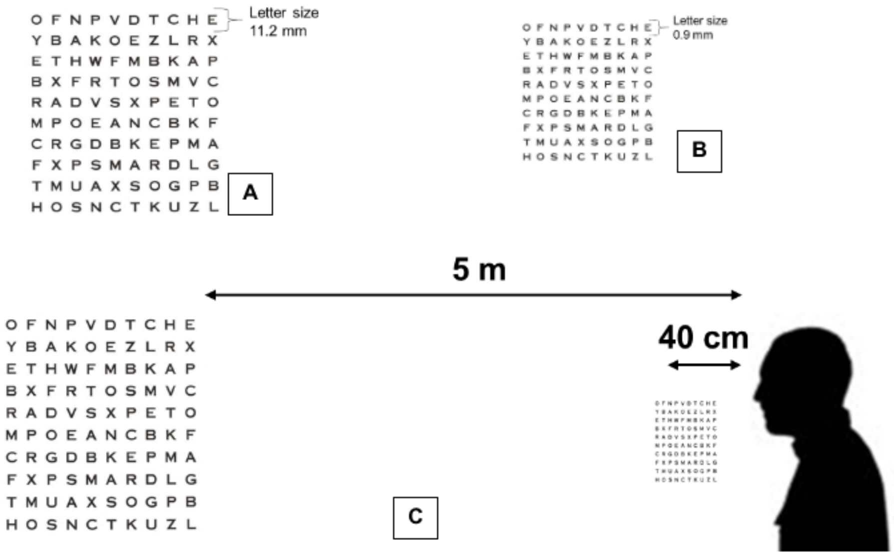


Figure 3. Accommodative Facility Testing Materials and Setup

Note: A) 5 m Hart Chart, B) 40 cm Heart Chart, and C) Test Setup

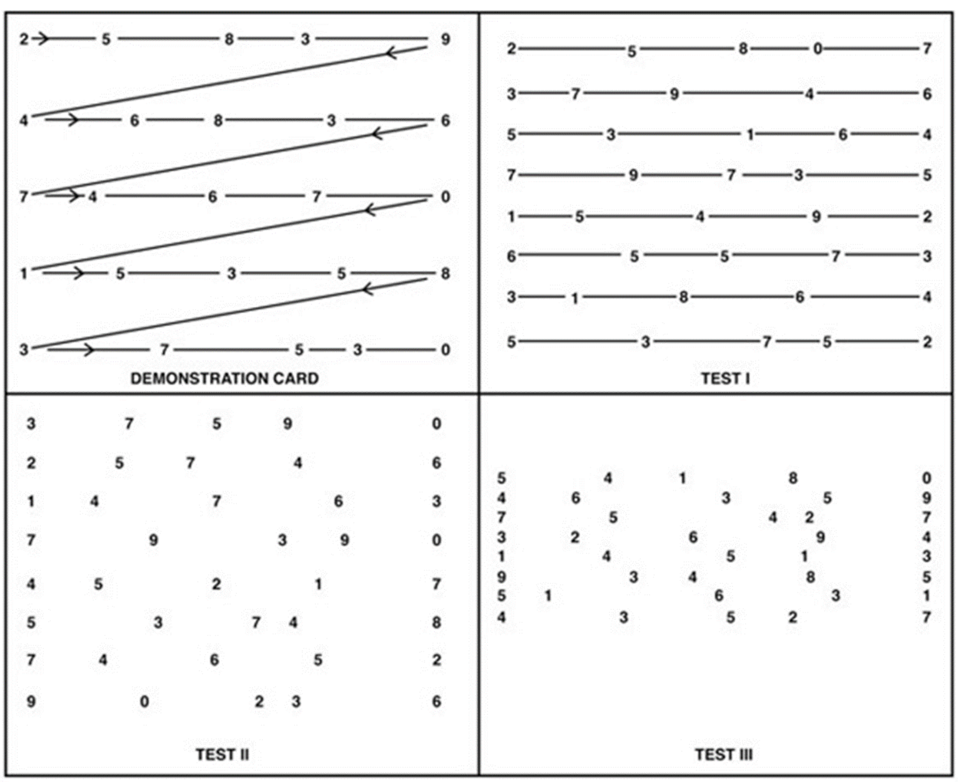


Figure 4. King Devick Test Materials

The ActiGraph wristwatch provided to the participant utilizes a solid state 3-axis micro electro-mechanical system (MEMS) accelerometer and filtering algorithm to detect daily sleep and step count. The participant is instructed to wear the watch 24-7, except while showering, to preserve the fabric band around the wrist. Each watch is initialized to collect data at 60 Hz, and is programmed to the BMI, wrist orientation, and skin color of the participant. The data collected will be used to support post-concussion recommendations.

Text message surveys are used to collect daily symptom prevalence among participants. A researcher messages participants four times daily, once at 9 am, 1 pm, 5 pm, and 9 pm, and askes the participant to report the severity of six symptoms, and will read as follows:

Please rate your current symptoms on a 0-10 scale (0 = none, 10 = most severe).

A. Headache
B. Dizziness
C. Difficulty Concentrating
D. Fatigue
E. Anxiety
F. Sensitivity to Light

Patients will be told to respond to the text messages in the following format (see participant instructions document):

A. 4 B. 2 C. 8 D. 0 E. 1 F. 6

Figure 5. Outline of Daily Text Message Questions

These particular symptoms were chosen due to their high prevalence post-concussion (headache, dizziness, difficulty concentrating, fatigue, and sensitivity to light) [9,25] or amongst the general population (anxiety).[21] These symptoms also represent the four domains of functionality of concussion (Table 1). [4] The data collected is recorded in an excel spreadsheet and will be used to support post-concussion recommendations.

Finally, phone call surveys are used to collect information on daily behaviors, referencing the time between the last phone call and the current call. The phone call is completed at 6pm, and therefore asks the participant to report data from 6pm the previous day to 6pm on the day of the current phone call. The phone call collects data on beverage consumption (water, alcohol, caffeine), class attendance, screen time, the time spent listening to music, and physical activity. Refer to Figure 6 for the script used by the researcher during the call. The data collected from the call is recorded in an excel spreadsheet and will be used to support post-concussion recommendations.

Daily Phone Call Questions Script

"All questions are referencing the period of time between your last phone call, till now"

1. "How many 8 oz servings of water did you drink?"
2. "How much caffeine did you drink? For example, soft drinks coffee or tea enter. As a reference a typical bottled soft drink is 16 oz?"
3. "How much alcohol did you drink? As a reference a typical can of beer is 12 oz?"
4. "What classes did you attend?" (types of classes: math, science, history, business, computer-based, engineering, literature, language, marketing, art, music)
5. ***IF THEY ATTENDED CLASSES***
    a. "Did you feel better, worse, or no change during those classes? For example, you can say, in math I felt worse, in art I felt no change".
    b. "Which of these classes were completed online today?"
        i. "How did you participate in this class and why? For example, you can say I watched and listened to the lecture in real time, I only listened to the lecture in real time, I utilized the recording of the lecture and watched or just listened.
6. "How much screen time have you engaged in? For example, TV, texting, or computer"
7. "How much time have you spent listening to music outside of class?
8. "Have you performed any physical activity?"
9. ***IF YES*** "What was the type and duration of physical activity you performed? For example, you could say, I rode a stationary bike for 30 minutes".

Figure 6. Outline of Daily Phone Call Questions

3.4 Data Analysis

3.4.1 Post Concussion Recommendations

Data collected through symptom and daily behavior surveys from text messages and phone calls, respectively, was analyzed using a mixed-effects regression model. This type of model allows for accommodation of both repeated measurements within-day (symptom prevalence), as well as between-days (behaviors and symptom prevalence) throughout recovery. The six symptoms evaluated in the daily text messages represent the dependent variables to be modeled against thirteen independent variables: physical activity, screen time usage, music usage time, water intake, alcohol intake, class attendance, all from the daily phone calls step count and time asleep, from the ActiGraph watch and gender, history of migraine headaches, anxiety, and concussion, from the demographic information. Time, in hours, post-injury was treated as a continuous independent variable within the model as well.

Minitab, a statistical software was used to run the analysis of variance (ANOVA) mixed effects regression model to determine the type of behaviors that influence symptom severity. To obtain residual plots that follow all assumptions (normal, constant variance, and random distribution of residuals), the response variables (symptom prevalence) were transformed using the natural log, where a response of 0 was treated as 0.0000000001. In these models the natural log of the symptoms were treated as the response, while gender, history of concussion, history of anxiety, and history of headache were all treated as fixed factors. Time in hours post-injury, water intake (8 oz increments), caffeine intake (oz), alcohol consumption (oz), screen time (min), music listened to (min), class attendance (0=no;1=yes), physical activity (0=no;1=yes), sleep duration (hours), and number of steps were treated as covariates in the model.

Once set-up and run, the residual plots were checked to ensure all ANOVA statistical test assumptions were met. All of the symptoms regression models met the assumptions except for the symptom of dizziness. Upon further evaluation, utilizing histogram and scatterplots of the residuals for dizziness, a pattern causing the non-normality of the data was identified among the data points when dizziness was reported as a 0 by a participant and when it was scored above 0. In order to obtain meaningful results and recommendations post-concussion for managing dizziness, the data for dizziness was subset into symptom severity of 0 and everything else. For the subset of data where dizziness was 0, basic statistic correlations were used to identify relationships between all other variables in the model. For the subset of data where dizziness was scored above 0, the same mixed effects model described above was fit, to determine the significant factors that influence concussion if dizziness was at least a 1.

3.4.2 Prognostics

Data collected from the oculomotor tests utilized linear regression to correlate each set of pre-RTL NPC, KD, AF, scores (immediately following when the informed consent is signed) to RTL recovery time (total hours between injury and completion of RTL criteria). The statistical software, Minitab, was used to estimate the regression. This regression model used the oculomotor scores (NPC, AF, and KD) as predictors of RTL, with all significant behaviors identified previously (water intake, caffeine intake, alcohol consumption, screen time, music listened to, hours of sleep, step count, class attendance, physical activity, and gender) in the model as well. To create this model, the behaviors for each subject were averaged throughout their entire recovery time (length of the study), in order to perform the regression. In this data, the binary variables are averaged to estimate the % of time during recovery that class was attended, or some form of physical activity was performed. In order to obtain comparable AF score results, the Hart Chart was coded from character 0 to 100, where the final score subtracted any errors from coded location on the chart. This allows us to identify the true number of characters read correctly. For example, a test location of column 7, row D (code of 37) with three errors correlates to a score of 34 (Figure 7). The higher the score, the better the subject performed, or the farther they got through the chart during the test. Furthermore, the higher the score also means that more near-far transitions were completed. In contrast, NPC and KD scores that were lower, signified better performance.

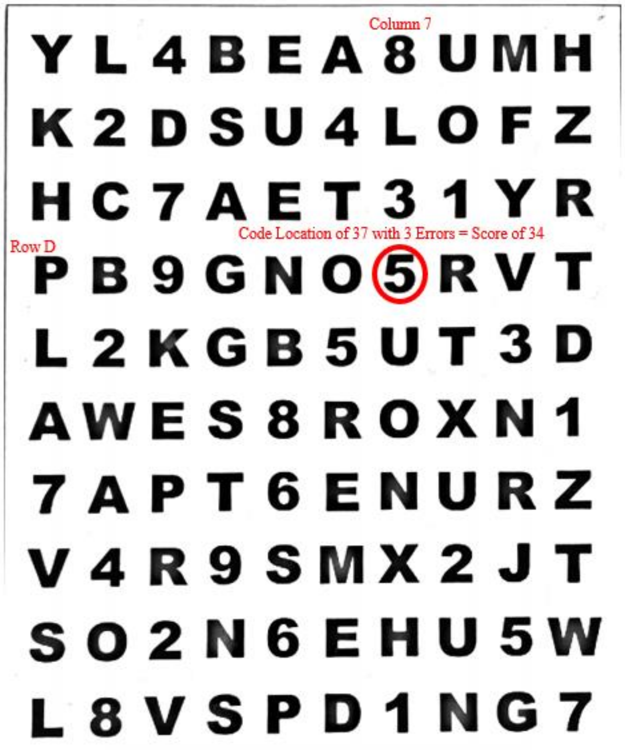


Figure 7. Example of Scored Hart Chart for Analysis

Logistical regressions were also utilized to associate oculomotor scores and binary RTL recovery time, normal (≤ 14 days) and prolonged (> 14 days). This will be analyzed using k-means clustering (k = 2) with pre-RTL NPC, KD, AF scores to introduce a clinical cutoff value, separating low and high scores for each test. A paired t-test was used to determine if the mean of the differences between an individual participants post-concussion oculomotor scores and RTL completion recovery scores differ from zero to understand if the test are good identifiers of improved performance and recovery in the classroom setting throughout recovery.

3.4.3 RIT Policy Comparison

Lastly, RIT was utilized as a case analysis on the practices of RTL, including support from the Disability Services Office (DSO) for students who have obtained medical requests for accommodations following a concussion. This academic accommodation approval process was observed and analyzed, for both the non-athlete student and student-athlete populations. To obtain information on the DSO accommodation process, Shelley Zoeke, former Associate Director of Disability Services, was interviewed, and asked to describe the DSO accommodation process and how the DSO process accommodates students with temporary disabilities like concussion. Information on how the student concussion is managed was gathered from working within the athletic training room on campus and seeing first-hand concussion care.

The combined data collected in the study and throughout literature, quantitative and qualitative, was used to compare the current RIT policy to current recommendation and will seek to suggest further RTL plans specific to college management, used by academic and clinical stakeholders, to address any shortcomings. This plan introduced a preliminary college RTL protocol, justifying separation between college and pediatric RTL protocols.

4. Findings

4.1 Demographic Data

The study data contained fifteen full-time undergraduate college student-athletes (seven male, eight female) from the Rochester Institute of Technology with an average age of 20.1 ± 1.4 years, who were diagnosed with a concussion by a member of the RIT Sports Medicine team.

4.2 Post-Concussion Recommendations

4.2.1. Beneficial Factors for Concussion Symptom Recovery

The study identified overall time, caffeine intake, alcohol consumption, screen time, music listened to, physical activity, sleep duration, step count, and gender as significant beneficial factors associated with concussion symptom resolution (Figure 8). Overall time was a significant factor altering headache, difficulty concentrating, fatigue, anxiety, and sensitivity to light with estimate values of -0.031 (p = 0.000), -0.038 (p = 0.000), -0.037 (p = 0.000), -0.035 (p = 0.000), and -0.034 (p = 0.000), respectively. This indicates a 3.1%, 3.8%, 3.7%, 3.5%, and 3.4% reduction in symptom prevalence per hour of time post injury, respectively. Caffeine intake was a significant factor associated with a reduction in headache, difficulty concentrating, and sensitivity to light with estimate values of -0.253 (p = 0.001), -0.198 (p = 0.009), and -0.1811 (p = 0.008) indicating a 25.3%, 19.8%, and 18.11% reduction in symptom prevalence per oz of caffeine consumed over the course of recovery, respectively. With an estimate value of -0.168 (p = 0.000) and -0.163 (p = 0.001), alcohol consumption was correlated with reducing anxiety and sensitivity to light by 16.8% and 16.3% for every oz of alcohol consumed throughout recovery, respectively. Screen time was a significant factor in reducing anxiety with an estimate value of -0.008 (p = 0.013), indicating a 0.8% reduction in anxiety for every minute of screen time over the course of recovery. Music listened to was correlated with a reduction in dizziness with an estimate value of -0.002 (p =

0.005), indicating a 0.2% reduction in symptom severity per minute of music listened to. The presence of physical activity (coded as 1) was a associated with a reduction in difficulty concentrating, fatigue, and sensitivity to light with estimate values of -0.81 (p = 0.046), -0.85 (p = 0.025), and -0.98 (p = 0.000), respectively. Sleep duration was a significant factor in altering dizziness, difficulty concentrating, fatigue, and sensitivity to light with estimate values of -0.0004 (p = 0.034) , -0.0054 (p = 0.005), -0.0099 (p = 0.000), and -0.0048 (p = 0.005), indicating a reduction in symptom severity by 0.04, 0.54, 0.99. and 0.48% per minute of sleep over the course of recovery. Step count was correlated with a reduction in headache, fatigue, and sensitivity to light with estimate values of -0.0006 (p = 0.000), -0.0003 (p = 0.036), and -0.0005 (p = 0.000), indicating a 0.06%, 0.03%, and 0.05% reduction per every additional step taken throughout recovery, respectively. Lastly females had a slight significant relationship on fatigue outcome, with an estimate value of -0.99 (p = 0.040). Refer to Table 5 for a summary for a summary of the results.

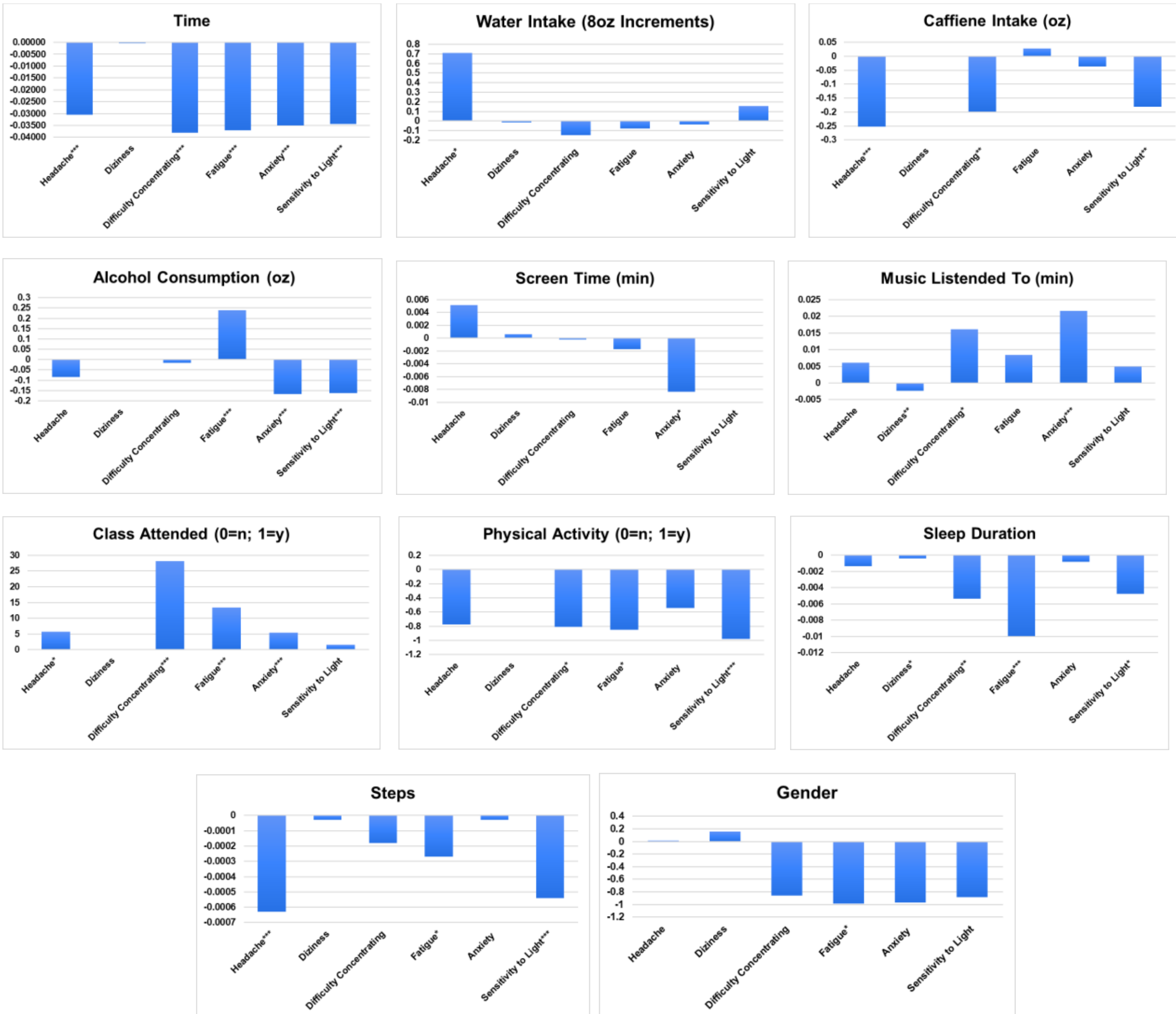


Figure 8. Behavioral Activities vs. Symptom Prevalence Plots

Table 5. Behavioral Variables and Symptom Prevalence Associations

Behavioral Variable	Headache		Dizziness		Difficulty Concentrating		Fatigue		Anxiety		Sensitivity to Light	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
Time (hour post-injury)	-0.0305***	0.000	-0.0004	0.229	-0.0380***	0.000	-0.0370***	0.000	-0.0350***	0.000	-0.0343***	0.000
Water Intake (8 oz servings)	0.7090*	0.034	-0.0131	0.690	-0.1464	0.499	-0.0798	0.723	-0.0334	0.848	0.1574	0.479
Caffeine Intake (oz)	-0.2530***	0.001	0.0022	0.909	-0.1987**	0.009	0.0278	0.747	-0.0372	0.543	-0.1811**	0.008
Alcohol Consumption (oz)	-0.0844	0.166	0.0017	0.866	-0.0154	0.793	0.2391***	0.000	-0.1681***	0.000	-0.1632***	0.001
Screen Time (min)	0.0052	0.298	0.0001	0.370	-0.0002	0.971	-0.0017	0.711	-0.0084*	0.013	-1.6E-05	0.997
Music Listened To (min)	0.0062	0.371	-0.0024**	0.005	0.0162*	0.012	0.0084	0.192	0.0216***	0.000	0.0050	0.382
Class is Attended	5.7910*	0.014	0.0782	0.363	28.1042***	0.000	13.4300***	0.000	5.4765***	0.000	1.6570	0.127
Physical Activity (presence of)	-0.7725	0.100	0.0096	0.934	-0.8109*	0.046	-0.8482*	0.025	-0.5415	0.201	-0.9809***	0.000
Sleep Duration (min)	-0.0014	0.509	-0.0004*	0.034	-0.0054**	0.005	-0.0099***	0.000	-0.0009	0.542	-0.0048*	0.005
Step Count	-0.0006***	0.000	-2.7E-05	0.145	0.0002	0.158	-0.0003*	0.036	-2.8E-05	0.761	-0.0005***	0.000
Gender (female)	0.0106	0.966	0.1556	0.463	-0.8641	0.368	-0.9900*	0.040	-0.9696	0.185	-0.8864	0.231
No Hx of Headache	0.0040	0.999	-0.2432	0.471	-0.9391	0.582	-0.9888	0.347	-0.8994	0.695	3.8049	0.701
No Hx of Anxiety	-0.9775	0.398	0.4481	0.285	-0.7055	0.775	-0.3836	0.903	5.7191	0.702	-0.6797	0.742
No Hx of Concussion	-0.5148	0.748	0.0665	0.692	-0.1243	0.952	-0.8720	0.322	-0.9691	0.192	-0.7914	0.383

*p<0.05, **p<0.01, ***p<0.001
Data are displayed as estimate values for symptoms on a scale of 0 to 10. Level of significance was set at p<0.05.
Hx: history

4.2.2 Adverse Factors for Concussion Symptom Recovery

The study identified that water intake, alcohol consumption, music listened to, and class attendance were associated with exacerbated symptoms throughout recovery (Figure 8, Table 5). Water intake was a significant factor in increasing headache with an estimate value of 0.71 ($p = 0.034$), indicating a 71% increase in headache for every 8 oz serving of water consumed throughout recovery. Alcohol consumption had an estimate value of 0.24 ($p = 0.000$) for fatigue, indicating a 24% increase in symptom severity for every ounce of alcohol consumed throughout recovery. Anxiety was significantly impacted by the time spent listening to music where the 0.022 ($p = 0.000$) estimate value from the analysis indicates anxiety worsens by 2.2% for every additional minute of music listened to throughout recovery. Class attendance was analyzed in a binary fashion (went to class or did not go to class). The result show that going to class can significantly increase symptoms of headache, difficulty concentrating, fatigue, and anxiety, resulting in estimate values of 5.79 ($p = 0.014$), 28.10 ($p = 0.000$), 13.43 ($p = 0.000$), and 5.48 ($p = 0.000$), respectively. These results indicate that attending class may increase headache, difficulty concentrating, fatigue, and anxiety by 579, 2810, 1343, and 584%, respectively.

4.2.3 Exit Survey: Student Perspectives on Recovery

A Qualtrics exit survey was completed by each individual subject to obtain student perspectives around class attendance and academic accommodations throughout their recovery. When asked, "During your recovery which school subject(s) was/were the most difficult?", 46.7% (7/15) reported math-based (including engineering) courses to be the most difficult. Two participants identified science to be the most difficult, while another two identified computer-based classes to be the most difficult. Two additional students identified art courses to be the most difficult, however both art courses identified (digital design and photography) require increased use of screen time. One student identified writing courses to be the most challenging, while the remaining student stated that none of their courses were difficult. Interestingly, 73% (11/15) of subjects identified that the courses related to their major were most difficult. When asked to identify courses that were least difficult, 26.7% (4/15) reported science-based courses, while six students identified social science (3/15) and business courses (3/15) to be least difficult. Two students expressed that math-based courses were the least difficult, while the remaining three students identified a wellness course (first year experience class), writing course, and no courses to be the least difficult, respectively.

Of the fifteen students who participated in the study, when asked "What academic accommodations did you receive during your recovery?", 40% (6/15) of students identified they did not receive academic accommodations, while another 40% were provided with additional time on assignments throughout recovery. Of the 40% of students who received additional time on assignments, 66.7% (6/9) of them identified this accommodation as the most helpful during their recovery. Thirty three percent (5/15) of participants were provided with excused absences from class, with 80% (4/5) of them identifying it as a helpful accommodation throughout their recovery.

Of the 60% (9/15) of students who received some type of academic accommodation, 56% (5/9) of them received the accommodation from the RIT DSO, while the remaining 44% (4/9) received the accommodations by working directly with their professors. One student identified that he tried to work with the DSO but could not schedule an appointment with them before his symptoms resolved, and only received accommodations from some of his professors throughout their recovery. He was included in the group of students who received academic accommodations from a professor.

When asked "Overall, what made you feel better?", 89.7% (13/15) of students identified rest/sleep/doing nothing as beneficial behaviors throughout their recovery, while 20% (3/15) identified limiting screen time as a beneficial behavior. Another 20% of students also identified not participating in any physical activity and working with the athletic trainers were factors that they felt aided their recovery. When asked "Did you alter your note taking method because of your concussion?" four students identified they altered their note taking method to reduce the time spent in front of a screen in order to limit symptoms.

4.3 Prognostics

4.3.1 Regressions

The regression of pre-RTL oculomotor scores versus RTL time, incorporating significant daily behaviors, identified that the NPC score ($p = 0.002$), AF score ($p = 0.004$), and KD score ($p = 0.005$) were significant factors in predicting RTL. See Table 6. The regression also showed that all behaviors were significant in the model as well: average water intake in 8 oz servings ($p = 0.003$), average caffeine intake in oz ($p = 0.004$), average class attendance ($p = 0.001$), average participation in physical activity ($p = 0.002$), average step count ($p = 0.008$), average music listened to in minutes per day ($p = 0.010$), average sleep duration ($p = 0.013$), average alcohol consumption in oz ($p = 0.006$), average screen time ($p = 0.002$) and participant gender ($p = 0.003$) were all significant in the regression. Refer to Table 6 and Table 7 for the complete results of the regression and the regression equation, respectively.

Table 6. Oculomotor Scores and Behavior Coefficients of the Regression

Term	Coefficient	p-value
Constant	418.65	0.009
NPC Score	69.962	0.002
AF Score	5.2596	0.004
KD Score	5.9560	0.005
Average Water Intake (8 oz Servings)	32.749	0.003
Average Caffeine Intake (oz)	9.0357	0.004
Average Class Attendance	-3931.78	0.001
Average Performance of Physical Activity	910.92	0.002
Average Step Count	0.021075	0.008
Average Minutes of Music Listened To	-0.60435	0.010
Average Minutes of Sleep	-0.5129	0.013
Average Alcohol Consumption (oz)	24.060	0.006
Average Minutes of Screen Time	-1.67486	0.002
Gender (Male)	260.92	0.003

*p<0.05, **p<0.01, ***p<0.001

Table 7. Regression Estimate of RTL Time

RTL Estimation from Linear Regression
Female RTL Time = 418.65 + 69.962 NPC Score + 5.2596 AF Score + 5.9560 KD Score + 32.749 Average Water Intake + 9.0357 Average Caffeine Intake - 3931.78 Average Class Attendance + 910.92 Average Performance of Physical Activity + 0.021075 Average Step Count - 0.60435 Average Minutes of Music Listened To - 0.5129 Average Minutes of Sleep + 24.060 Average Alcohol Consumption - 1.67486 Average Minutes of Screen Time
Male RTL Time = 679.58 + 69.962 NPC Score + 5.2596 AF Score + 5.9560 KD Score + 32.749 Average Water Intake + 9.0357 Average Caffeine Intake - 3931.78 Average Class Attendance + 910.92 Average Performance of Physical Activity + 0.021075 Average Step Count - 0.60435 Average Minutes of Music Listened To - 0.5129 Average Minutes of Sleep + 24.060 Average Alcohol Consumption - 1.67486 Average Minutes of Screen Time

4.3.2 k-means Clustering

k-means clusters resulted in the creation of high and low NPC, AF, and KD Scores as follows in order to estimate cutoff values for performance on oculomotor tests.

Table 8. k-means Cluster of Oculomotor Scores into "High" and "Low" Scores

Oculomotor Test	Low Score (Cluster 1)	High Score (Cluster 2)
NPC	< 11.088	> 11.088
AF	< 72.2667	> 72.2667
KD	< 57.1067	> 57.1067

Following the dichotomy of oculomotor scores into “high” and “low, and RTL time into “normal” and “prolonged”, binary logistic regression was utilized to determine if scores could prognostic binary RTL time, where “normal” was less than or equal to 336 hours and “prolonged” is greater than 336 hours. Due to limitations in sample size and the large number of covariates, there were not enough degrees of freedom to present usable results beyond the initial regression of scores and time.

4.3.3 Supplemental Analyses

Limitations in the availability of the regression to prognosticate RTL presented the opportunity to alternatively analyze the data using scatterplots, bubble plots, dotplots, and paired t-test hypothesis testing. Statistical plots were then utilized to view any trends within the data, in order to present qualitative findings between oculomotor scores and RTL time. A scatterplot of each score to RTL was created, as seen in Figure 9. Additionally, a scatter plot of each score to average class attendance was also performed, Figure 10.

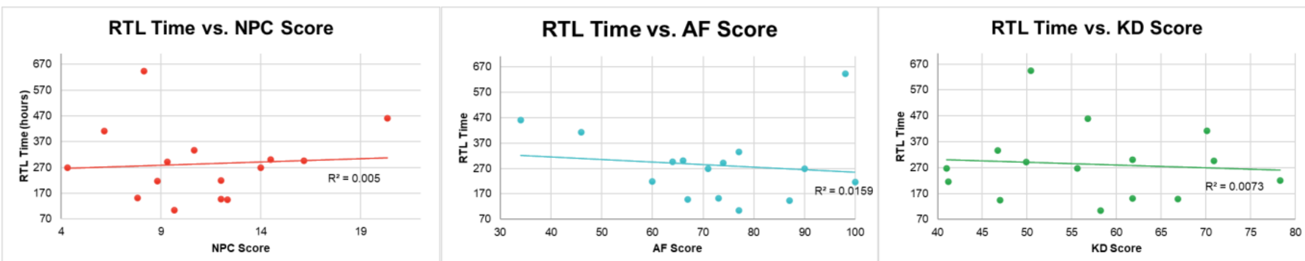


Figure 9. Scatterplot of RTL Time and Oculomotor Scores

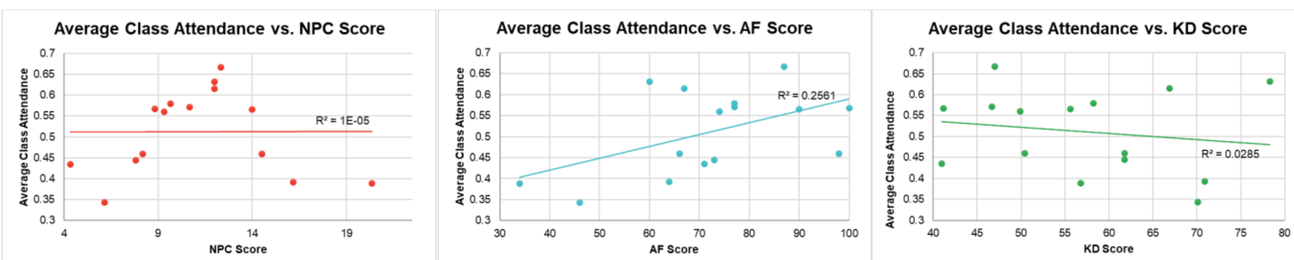


Figure 10. Scatterplot of Average Class Attendance and Oculomotor Scores

Bubble plot charts in Minitab were also used to understand potential relationships between oculomotor scores and the choice of a participant on whether to take academic accommodations or not, based off of their exit survey response. A "0" means a student did not receive academic accommodations while a "1" means they did, either from the DSO office or a professor. The size of the bubble corresponds to the participants RTL recovery time, while the color represents if their RTL time fell under "normal" or prolonged". The reference line on each plot represents the cluster cutoffs. Refer to Figure 11 below.

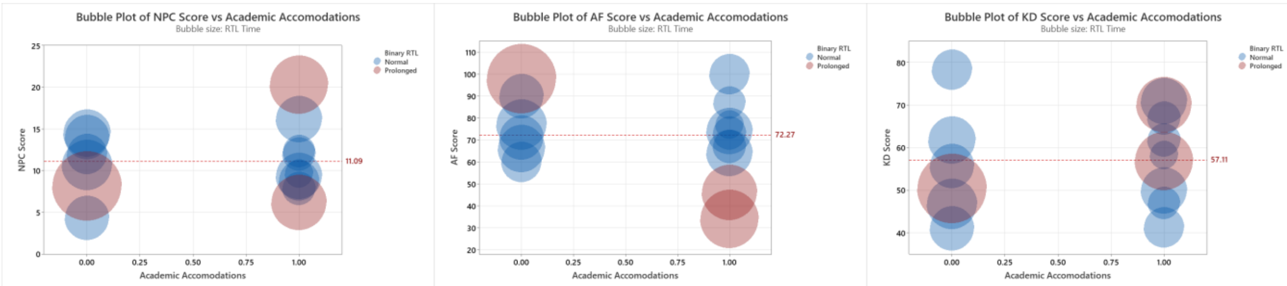


Figure 11. Bubble Plot of Oculomotor Score and Choice of Academic Accommodation.

Note: Bubble Size is Based on RTL Time. Academic accommodation of "0" represents no use of accommodations within the classroom while academic accommodation of "1" represents use of accommodations either from the DSO office or from professors, as reported by participants in the exit survey. Blue bubbles represent participants with "Normal" recovery while red bubbles represent participants with "Prolonged" recovery.

Lastly, a dotplot of RTL time and academic accommodations shows there is a soft relationship between a lower RTL time when academic accommodations were pursued, Figure 12.

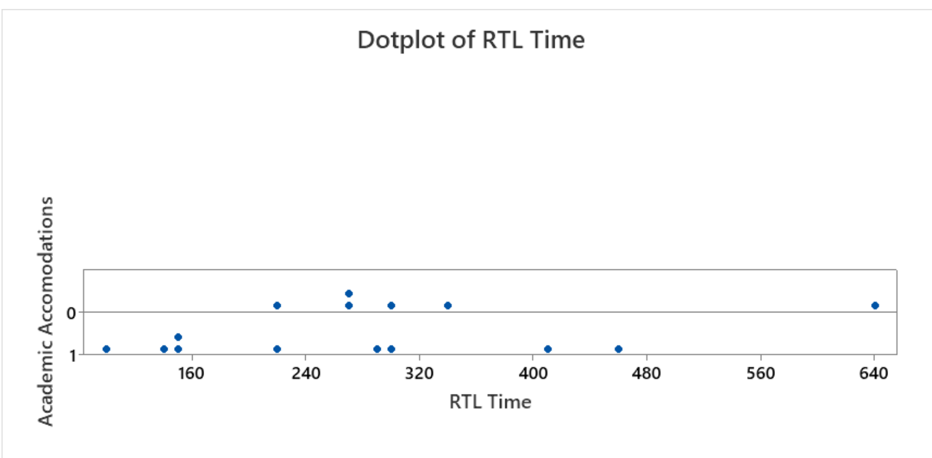


Figure 12. Dotplot of Academic Accommodation and RTL Time

Note: Academic accommodation of "0" represents no use of accommodations within the classroom while academic accommodation of "1" represents use of accommodations either from the DSO office or from professors, as reported by participants in the exit survey.

Paired t-test was also used to better understand if differences exist in oculomotor scores performed following the concussion (COI+ Scores or μ_1) and scores performed when completion criteria or RTL recovery has occurred (RTL Scores or μ_2). The paired t-test results showcase that the null hypothesis ($\mu_1 - \mu_2 = 0$) can be rejected for AF (p = 0.000) and KD (p = 0.001) in favor of the alternate hypothesis that $\mu_1 - \mu_2 > 0$. In other words, the paired t-test shows that AF and KD scores performed once completion criteria have been met (participants have fully RTL), are less than the AF and KD scores performed within seven days of a concussion. Paired t-test results are shown in Table 9.

Table 9. Paired t-test Between Post-Concussion and RTL Oculomotor Scores

Oculomotor Test	COI+ Score Mean (μ_1)	RTL Score Mean (μ_2)	Null Hypothesis	Alternate Hypothesis	p-Value
NPC	11.09	10.22			0.114
AF	72.27	89.80	$\mu_1 - \mu_2 = 0$	$\mu_1 - \mu_2 > 0$	0.000
KD	57.11	50.15			0.001

4.4 RIT Policy Comparison

In this next section, I will present my findings from completing an investigation of the Rochester Institute of Technology's policies and processes of receiving academic accommodations when a student or student-athlete suffers from a concussion.

4.4.1 Process of Receiving DSO Accommodations

4.4.1.1 Student-Athlete

When a student-athlete suffers a concussion, they are evaluated and diagnosed by an RIT athletic trainer (AT) or physician. Upon diagnosis, the athlete is placed in RTP protocol and meets with the physician to discuss the RTP process, as well as be provided information on obtaining DSO academic accommodations if they choose to do so. The physician/AT notifies the DSO and send official documentation of the injury and provides the athlete with the contact information and application link for DSO accommodations. If the athlete chooses to obtain accommodations, they are instructed to use this contact information to fill out the online application form or call the DSO directly for support. In the application, the student registers with the DSO by providing demographic information, information about the disability (or the injury in this case), and any previously utilized accommodations, if applicable. Upon submission of the application, and review by the office for approval to grant accommodations, a meeting between the student-athlete and the DSO coordinator will be set up. During this meeting, the student and coordinator work to identify which accommodations to put in place, based on symptomology, class type, and assignment schedule. The student uses this time to have final say in their accommodation selection. Upon complete selection by the student, the DSO will approve the accommodation selection, which can occur directly at the meeting. Upon DSO approval, the selected accommodation for each course is sent to the respective professor/faculty member for signature of approval. If a professor does not sign for approval, due to the accommodation not foreseen as feasible in their classroom setting, the DSO works with the student-athlete and professor to alter the request in a way to ensure the student is receiving the necessary accommodations by the professor.

Given the process described above, the average length of this process is typically one week but can be longer or shorter depending on the availability of the athlete to meet with the coordinator and how busy the DSO is itself. Furthermore, if the injury occurs outside of operating hours, like in the evening or on the weekend, the process could take longer to obtain the accommodations.

In terms of the length of the accommodation, the RIT DSO accommodation database works on a semesterly schedule. In other words, unless the student actively notifies the DSO that the accommodations are no longer needed, there is no formal way to limit the length of an accommodation for the length of the athletes recovery. However, if there are any changes due to post-concussion syndrome, persistent post-concussive symptoms, the athlete can request to meet with the coordinator again and alter/add accommodations as needed, provided the AT/physician documents the continual injury with the office. During the interview, it was noted that most student-athletes work with their professors to let them know the accommodations are no longer needed.

There are some cases where students will instead work directly with the professor in receiving academic accommodations, instead of formally going through the DSO. In these cases, professors will sometimes reach out to the DSO to verify the injury was documented or request that the student obtains DSO approval. In some cases, the professor will provide initial accommodations until the DSO accommodation process is approved to accommodate the delay in obtaining accommodations due to the lengthy process of doing so.

4.4.1.2 Non-Athlete Student

The process for a non-athlete student on the RIT campus who is suffering from a concussion is very similar to that of the student athletes. However, after filling out the application online, the student must provide their own documentation of the injury. The DSO accepts documentation like a physicians note from a primary care, urgent care, or student health center. Documents like discharge papers are also accepted as long as the injury, care process and recommendations, are documented with the discharge papers as well. Once the application is submitted the same process of DSO decision to grant accommodations, a meeting is set-up with the student to discuss their challenges and appropriate accommodations. These accommodations are selected, approved by the DSO, and sent to the professor for signature of acceptance and approval. Because of the additional documentation step, the approval process for non-athlete students may take longer due to the need for obtaining this documentation.

The challenges faced within the non-athlete student is the knowledge that academic accommodations are available to them; Shelley noted that if the student was diagnosed with the student health center on campus or discusses their injury with their instructors, they are more likely to seek accommodations with the DSO. Otherwise, the student may not know the office is available for them, or that they are eligible to receive official accommodations. Refer to Figure 13 for differences in the path to receiving academic accommodations between student-athletes and non-athlete students.

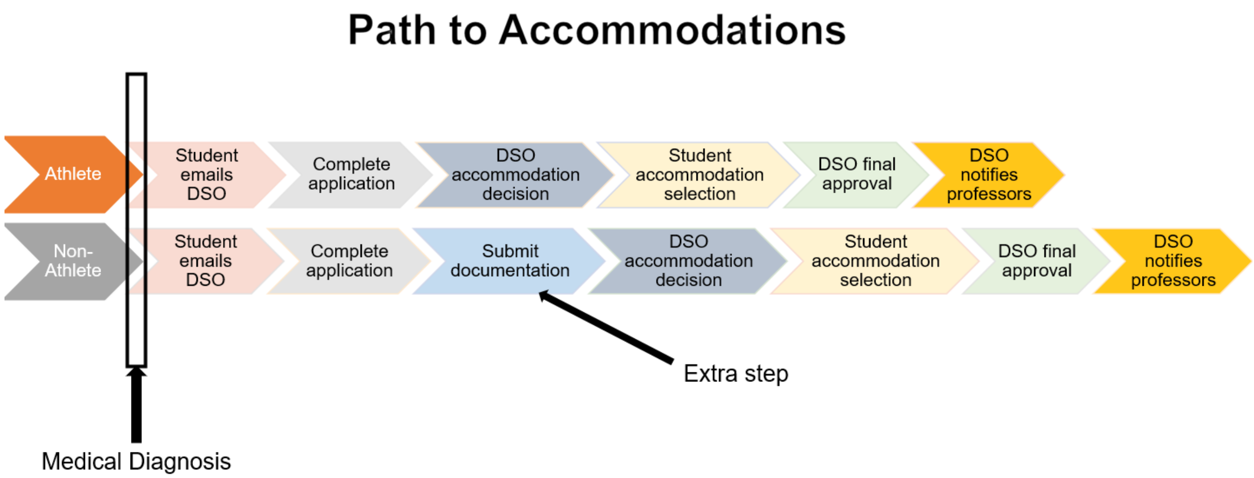


Figure 13. Differences in the Path to Receiving Academic Accommodation Between Student-Athletes and General (Non-Athlete Students) at RIT

4.4.2 DSO Coordinator Perspective

At the time of the interview Shelley had worked with the RIT DSO for 10 years and was a special education teacher at a school for students with disabilities for 13 years prior. When asked: "How do you know which accommodations to suggest to a student or student-athlete seeking accommodations for a concussion?", she responded by saying a lot of her decision-making process and guidance is based on the symptoms a student is having, the current challenges they are facing in the classroom or on assignments and utilizing her experience in the role for multiple years as guidance for which accommodations have been the most requested and most helpful from former students. Additionally, since her role was specialized to working with students diagnosed with a concussion, she had done some personal research to better understand the sequelae of injury, and the most common accommodations provided for care of the injury in the classroom. Furthermore, she expressed that someone newer in the role would have difficulty suggesting appropriate accommodations based off of symptom prevalence and challenges. Upon being asked what she felt would be beneficial for someone who works with students suffering from a concussion on learning about the injury, she said she would be interested in taking a training course or completing professional development on managing the injury and better understanding the challenges someone may face due to injury in the brain in order to bring additional skills and knowledge to support students.

Time spent interviewing the DSO coordinator identified the following potential changes to improve the process of receiving accommodations: utilizing a re-evaluation/check-in system to see if changes to accommodations are needed as symptoms change, having more insight on the medical/athletic side to understand what is already planned in terms of care and accommodations, using symptoms to recommend appropriate accommodations, as well as the introduction of a point person between academics and medical treatment to ensure care is standardized across all student populations and lines are not crossed in terms of treatment and recovery. Upon discussing these recommendations, Shelley expressed that these changes would be great, however the current bandwidth with the staff is very low due to understaffing challenges and the large amount of requests the DSO must process, as the DSO also works with the National Technical Institute for the Deaf, which is part of the RIT campus, and could limit the availability of the team to implement these recommendations.

4.4.3 Student Perspectives on Receiving Accommodations

Throughout the length of the study at RIT, all participants were asked to complete an exit survey and express their academic experience during recovery from their concussion. When asked if they received accommodations from the DSO, students who expressed they did, identified that they felt it was beneficial to their recovery. During their exit from the study researchers also asked students to describe their recovery process in terms of managing the return to the classroom. A common theme among participants is that they really used their symptoms to guide whether they went to class or sought out accommodations (either from DSO or the professor directly). Those who sought out DSO accommodations expressed the desire for the process to be faster, especially when they had professors who were unwilling to provide accommodations unless they were sent through the DSO. One student in particular sought out DSO accommodations, but was unsure if they ever got approved, because he was never able to schedule the appointment with the DSO coordinator before his symptoms had resolved (1 week following the initial injury). In his case, he was able to receive some accommodations directly from professors for some courses, but in others he was unable to receive accommodations like additional time on assignments, because he was never able to get an appointment with the DSO.

Students also expressed heavy reliance on their AT to guide them and provide recommendations for approaching RTL and RTP and utilizing their expertise for managing symptom prevalence. This provides evidence on the reliance of someone they closely work with to obtain guidance and support and identifies potential need for the AT to be more involved in RTL. Furthermore, the desire for a quicker process of receiving accommodations to ensure there are no repercussions for missing class or assignments and reduce anxiety around academic requirements while they are also trying to recover and reduce symptom prevalence further identifies the need of changes to the policy to ensure accommodations are received as soon as possible. Additionally, student perspectives and quantitative data of increased anxiety about missing assignments or class that would impact their academic outcome negatively with professors supports the need for university policy supporting removal from academic load (implementation of cognitive rest) for the first few days following the injury, similar to the 24–48-hour period of rest in the RTP protocol.

5. Discussion

5.1 Post-Concussion Recommendations

The first set of findings from this study identified eleven variables that produced significant associations with participants' concussion symptoms. To begin, I will introduce potential mechanisms as to why these factors are identified as beneficial or adverse associations to concussion symptoms, and thereby concussion recovery. Next, I will discuss potential implications of the common themes identified among participants in the exit survey from the study. Third I will synthesize the results of the prognostic ability of the oculomotor tests. Finally, I will utilize the quantitative findings to analyze RIT and the current return to learn practices for students following a concussion and discuss proposed changes and associated policy implications.

5.1.1 Beneficial and Adverse Behaviors in Concussion Recovery

Time, in total hours post-injury, was the first variable to show significant interaction with symptoms and is an implicit association as concussion symptoms are expected to normally resolve over time (within 14 days for adults and 28 days for children).[2] The data indicates that the presence of physical activity was associated with reduced symptoms of difficulty concentrating, fatigue, and sensitivity to light, corroborating emerging evidence advocating for the use of physical activity as medicine in concussion care from Leddy et al.[30,34–36], as well as preliminary associations found in a 2019 study by Bevilacqua et al..[18] However, participation in physical activity was dependent on the stage of RTP participants were in, as managed by their AT. The AT's at RIT do not directly utilize the protocol from Leddy and colleagues, due to time constrains. Instead, the RTP protocol from the fifth consensus statement from the CISG is utilized where physical activity cannot be started until symptoms are no longer present during stage 1, rest.[2] Furthermore, if an athlete who is cleared to participate in some form of physical activity chooses to forgo activity, this may have been a result of not feeling well due to increased symptom severity. For example, one participant began their first day of stage two activity in the RTP protocol on the 8th day following the injury and did not partake in any form of physical activity again until day 16 post-injury. Their overall recovery time was 23 days. Another subject began stage two of the RTP protocol on the 9th day following the injury and did not partake in any physical activity again for another seven days. Their overall recovery time was 22 days. On the other hand, a participant who began stage 2 of the RTP protocol began light activity 30 hours post-injury and continued to progress activity until full recovery on day 14. This participant was physically active daily, except for two days of recovery. Time of year may also affect physical activity, depending on if the athlete was in-season for their sport or not; an athlete in-season would have more practices/lifts per week than an athlete not in-season, effecting their activity level. Additionally, the data indicates that increased total daily step count throughout the recovery correlated with a reduced symptom prevalence of headache, fatigue, and sensitivity to light. These result corroborate findings from RTP exercise stages[2] and Leddy,[30,34–36] that even light exercise, like walking, can be associated with a reduction of concussive symptoms allowing the individual to perform physical activity.

Class attendance data indicates that attending class significantly increased symptoms of headache, difficulty concentrating, fatigue, and anxiety. For example, missed classes or course assignments could increase a student's anxiety about falling behind, especially when accommodations were not sought out or provided by a professor. Furthermore, if a participant is attending class, symptoms can worsen due to decreased ability to concentrate, process what they are hearing, and the utilization of cognitive function for increased amount of time, while their brain is using energy to recover. Exit survey responses on what courses were the most difficult explain some of the characteristics seen in symptomology as to why anxiety would be increased, even though class was attended. New difficulty in a course could increase anxiety within a student who is trying to perform well, but cannot due to the inherent limitations of cognitive activity following a concussion. When accommodations are not provided, a student who is attending class but isn't remembering, concentrating, or performing as well, would likely see a rise in anxiety about completing assignments, or taking exams. Childers and Hux utilized a phenomenological analysis to explore the phenomena of college life as experienced by college students who have been diagnosed with a concussion which corroborates the findings from this data set on the negative impact class attendance has on concentration, fatigue, and anxiety.[21] Furthermore, research and knowledge of concussion and RTL supports the relationship seen in the data, in that post-concussion cerebral blood flow is reduced due to deregulation of the autonomic nervous system. Increased cognitive or physical activity requires increased blood flow to perform tasks, but the dysregulation occurring from the injury does not allow for sufficient supply of oxygen and nutrients, leading to increased symptomology.[3]

Sleep duration data indicates that longer overall sleep duration was associated with a reduction of the the severity of dizziness, difficulty concentrating, fatigue, and sensitivity to light, corroborating some of the findings in the preliminary study by Bevilacqua et al.[18] Evidence from a study by Hoffman et al., showcases that individuals who experienced sleep deprivation (were awake longer or had more sleep disturbances) took longer to recover.[54] Results of a sleep study by Xie et al. showcased that sleep deprivation reduces the brains ability to naturally heal through reduction in glymphatic system function, speculating the link between decreased sleep and increase in concussion symptomology.[55]

Longer durations of music exposure were shown to have a negative association with difficulty concentrating and anxiety, while also having a beneficial relationship to dizziness.

Preliminary evidence from Turgeon et al. suggests that concussion can disrupt auditory processing and found that mechanisms of listening, and recognition are affected.[56] This evidence suggests that auditory stimuli, like music, makes it harder to concentrate on other tasks and can lead to an increase in symptomology. These findings may also suggest that processing of fast paced lectures could be affected, and lead to increased difficulty in concentrating and remembering in the classroom following a concussion.[56] Furthermore, as found in Bevilacqua et al., music exposure also negatively impacted difficulty concentrating. This phenomena was explained as a potential over stimulation of brain tissue partnered with the concurrent reduction of blood flow supplying metabolic demands following concussion as impacting auditory function.[18] Results from a post-concussion auditory/cognitive performance and symptom reporting study by Vander Werff and Rieger found significant effects between auditory symptoms/markers and increased symptom prevalence for common post-concussion symptoms like anxiety, and potentially explains the relationship seen in this analysis.[57] Very little evidence explains the association between listening to music and a related reduction in dizziness. One potential explanation could be centered around the ability of music therapy to help calm and relax a student, especially to improve pain, mood, and sleep quality in individuals who have experienced concussions, as described by Smith and Layman.[58] If students from the study listened to more music in the evening to aid sleep, or to relax throughout the day, a reduction in dizziness could be explained as a result of improved sleep due to the use of music to calm/relax an individual.

The data indicates that consumption of caffeine throughout recovery reduces symptoms of headache, difficulty concentrating, and sensitivity to light. Caffeine is a neurostimulator that has vasoconstrictive properties. In other words, caffeine causes the blood vessels to narrow, restricting blood flow, alleviating headache pain, when consumed in moderation.[59] Headache/migraine are caused by the dilation of blood vessels that lay on the surface of the brain, increasing blood volume and pressure, and leading to the pain associated with headaches. When caffeine is consumed, these vessels constrict to reduce this excess blood flow, and is expected to reduce pain by returning the enlarged vessels back to their normal state.[60] This could explain the relationships seen in the data of this study; a reduction of headache symptomology from caffeine consumption could improve the ability to concentrate on school activity by reducing pain. Contrastingly, there is a decreased supply of ATP during the first few days following a concussion, and when caffeine is consumed, ATPase activity is inhibited.[3,61] When in conjunction with the limited cerebral blood flow shown previously, it is expected that caffeine consumption may exacerbate the demand for energy experienced by the brain, worsening symptoms of headache. The positive relationships seen in our data suggest that caffeine was helpful because it was consumed later on in recovery, and in moderation, to dose the brain with enough stress to invoke pain reduction while students began attending classes again. Furthermore, caffeine consumption, in moderation, has been linked to increased attention, memory, and alertness due to increasing levels of choline in the brain, a compound that is used by the body to regulate memory, mood, muscle control (ex. pupil dilation for adjusting to light) and other functions.[62,63]

Overall consumption of water, in 8 oz servings, had an negative association with headache in our data. Despite statistical significance, this relationship is hard to delineate. Due to the nature of the study, the relationship here could have been influenced by other factors; increased water consumption among the athlete population compared to non-athlete individuals, and a small sample size of observations. The data also showed that reduction in anxiety was correlated with a total screen time throughout recovery. The majority of collegiate assignments are completed through the use of a screen, and therefore could be one potential explanation for the relationship seen in the data set. As noted by Childers and Hux, students who took more time away from class and classwork were more anxious about falling behind their peers in the class.[21] If participating in activities that required screen time allowed them to stay on top of coursework, anxiety around courses would be reduced, and could explain the relationship in this dataset. However, other studies suggest that increased screen time can increase anxiety,[18,64] demonstrating that this relationship should be investigated further. Gender data from the study indicated that females were associated with experiencing less fatigue compared to male counterparts, throughout recovery, contradicting previous literature that suggest the disposition of greater symptom severity among females.[64–67] These studies show that females often score higher than male counterparts for many symptoms, including fatigue. These results are difficult to explain and may just be a unique quality of the female participants in this study. Furthermore, this could be a result of the female participants in this study engaging in less behaviors that attenuate fatigue than their male counterparts.

Lastly, alcohol consumption showed significant interaction with symptoms of fatigue, anxiety, and sensitivity to light. The data indicated that alcohol consumption was associated with improved symptoms of anxiety and sensitivity to light but worsened symptoms of fatigue. Alcohol is a neuro-depressant that stimulates the inhibitory neurotransmitter GABA and inhibits the excitatory neurotransmitter glutamate, which in turn slows down neural activity and can make an individual feel more relaxed, or less anxious.[68] Furthermore, it is commonly known that alcohol impairs vision upon consumption and may explain the reduction in sensitivity to light within the dataset; reduced visual function from intoxication would make individuals less aware to changes in light, thereby experiencing less sensitivity to changes in lighting while intoxicated.[69] Alcohol also makes individuals more dehydrated due to the inhibition of vasopressin. This inhibition does not allow for aquaporins to be inserted into the collecting duct in the bladder. For these reasons, a large amount of dilute urine is expelled, causing dehydration. This dehydration triggers fatigue as a result of impacted sleep quality the following day, likely explaining the relationship seen in this study.[70]

The relationships presented within this section largely corroborate findings in the preliminary study of non-athlete college students by Bevilacqua et al. in 2019. However, some relationships presented here contrast their findings, or present new findings that require further investigation. The corroborating findings in this study provide promising results compared to previous work and can begin to suggest recommendations like symptom limited exercise therapy, cognitive rest, restricted class attendance, rest/sleep, light aerobic exercise (walking), moderate caffeine consumption, and reduced time spent listening to music, as part of guided care within RTL and RTP.

5.1.2 Student Provided Trends in RTL Concussion Recovery

The results of the exit survey indicate mathematics (47%) as the most difficult subject and limiting screen time (27%) to aid in their recovery during RTL. The present findings corroborate findings from Ransom et al., Bevilacqua et al., and Holmes et al., in that math was identified as the most difficult subject.[18,26,71] In the preliminary study by Bevilacqua, the difficulty experienced among various populations in mathematics was explained as a repercussion of decreased blood flow (i.e. less oxygen and nutrients) to the posterior cingulate and cerebellar regions of the brain. As supported from fMRI, these regions of the brain contribute to mathematical processing.[72,73] Furthermore, diffusion tensor imaging showcased abnormalities in the corpus collosums' commissural fibers which are commonly injured during concussion to correlate to patients who also identify mathematic performance difficulties.[18,73,74] Synthesizing the data further, of the 47%

of students who identified math as the hardest subject, 57% of them utilized academic accommodation. Among the 57%, three-fourths identified additional time on assignments as the most beneficial while the remaining student identified excused absences from class to be the most beneficial. This data corroborates findings from Ransom and Bevilacqua, that student's with increase difficulty with mathematics-based courses favored accommodations like additional time on exams or assignments and excused absence from class, likely to give injured neural tissue more time to conduct the required cognitive activities necessary to complete assignments.[18,26] The findings in this study, which corroborate three earlier studies, indicate that students in technical courses (math based) benefit from academic accommodations[18,26,71]. This showcases that RTL protocols/policies should require the use of academic accommodations in math heavy courses, to improve recovery time and symptomology among students.

Another trend among respondents centered around changes to note taking, due to sensitivity to light from a digital screen, agreeing with the reluctance of computer usage. Corroborating findings from Bevilacqua et al., Mansur et al. equates the sensitivity to screen time to the rapid flickering (refresh 60-times per second) of screens, provoking a sensitivity to light in concussed individuals.[75] When healthy, this refresh of computer screens is negligible and does not cause a sensitivity to light.[18,75] This deficit in concussed individuals may explain why four participants, who altered their note taking method away from digital notes, did so to limit the rise in the sensitivity to light symptom, when in class and taking notes by limiting screen time. Three of the four of these participants reported symptom prevalence for sensitivity to light immediately following intake into the study (3 or higher), supporting this anecdote from their exit survey. An additional three participants noted limiting screen time throughout recovery as much as possible. This perspective furthers our understanding of the appropriate accommodations and recommendations for concussed students as they return to the classroom: use of note takers and recommendation from medical personnel to avoid screen time.

The third common trend among this cohort centers around the use of academic accommodations. Exit survey data showed that 60% of participants sought some form of academic accommodations to aid in their recovery. Of those who received accommodations, 56% received accommodations from the DSO, while the remaining 44% received them directly through their professors. Student-athletes who received academic accommodations had an average recovery time of 247.1 ± 126.4 hours, compared to 339.3 ± 154.1 hours among their peers who did not seek out accommodations, however this difference was not statistically significant given this sample size. While not statistically significant, this evidence clearly suggests that academic accommodations were beneficial to recovery time. It would be interesting to see if non-athlete students being included in the study would add to this preliminary trend, especially if obtaining DSO approved accommodations is not as well guided, as it is for student-athletes. Associating these findings to the adverse effect class attendance had on symptom prevalence, the data can preliminarily suggest that return to class following a concussion increases symptomology and can prolong recovery, however when modified by academic accommodations, participants experience a therapeutic classroom.[26,40] The most common accommodation selected among participants was additional time on assignments (6/15), corroborating findings from past studies while also showcasing a greater percentage of accommodations used among RIT students than students at other universities.[40,76] This trend begins to highlight the need for increased education around concussion recovery, expected symptomology, and the resources students have on campus. Furthermore, improving education within the RIT faculty and staff population could also improve recovery for students and reduce the symptomology through improvement in choosing appropriate accommodations. Improved education is important as data recommends changes to management and care of concussion, yet 4/9 of our participants took accommodations from professors, signifying that some RIT faculty are already amenable to assisting concussion.

Finally, the most common trend identified among participants, was that resting (sleeping and doing nothing) was the most beneficial factor in their recovery. This corroborates the CISG consensus that a period of rest immediately following the injury plays a large role in overall recovery time and should be required for both RTL and RTP. This perspective identifies the need for supporting policy to not allow a student to immediately return to the classroom following their injury, to ensure proper rest.[2,22,77]

5.2 Prognostic Ability of Oculomotor Score on Concussion Recovery Time

The results of the regression between RTL time and oculomotor scores showcase that the NPC, AF, and KD eye tests have some statistical significance in being able to predict RTL time. Furthermore, all of the behaviors included in the model, were significant in predicting RTL time, matching the results of the mixed effects model. However, not all relationships (coefficients) were expected. AF score had a positive coefficient, meaning that scoring higher would lead to increased RTL time, which is not expected. As described earlier, those who score higher, performed better and had less difficulty transitioning between near and far. Furthermore, class attendance and music listened to have negative coefficients, meaning the higher percentage of class attended or the more music listened to, the quicker the RTL time, which is not expected based on the mixed effects model. In fact, all relationships in the regression are opposite of the effect in the mixed effects model, except average sleep time, NPC, and KD. This is not expected but could be a result of having to average all behaviors for each subject over the entire length of recovery in order to estimate a regression, since oculomotor scores immediately following the concussion were only taken on the first day of participation in the study, versus daily, like the behaviors and symptom reporting. The averaging of these behaviors, which impact symptomology and therefore RTL time likely impacted the relationship in the model. Although all variables are significant, it is difficult to interpret the regression equation, since not all terms corroborate the mixed effects model relationships. These results are likely due to the limited sample size. Further contributing is the high number of variables to include in the regression, while the sample size remains low.

Upon dichotomizing scores into “high” and “low” and RTL time into “normal” and “prolonged”, the regression of the scores and RTL time could no longer be estimated. Due to limitations in observations (participants) and the large number of variables to include in the regression, the degree of freedom for regression estimation was lost. Furthermore, the limit in sample size resulted in only three participants in the prolonged RTL category, and again limited the comparability (degrees of freedom) in the regression.

The results of the paired t-test showcase that there is a significant difference between COI+ and RTL scores for AF and KD eye tests, and that scores obtained when a student has met cognitive recovery criteria, in our study, are better than scores obtained within seven days of the concussion, when the brain is still trying to recover. This showcases the potential use of AF and KD tests to understand when a student is ready to return to the classroom and complete a graduated RTL protocol, similar to RTP, and could be used as a quantitative measure to guide return to full class attendance and academic activity.

No strong relationships are found among RTL time and oculomotor score scatterplots, however, a stronger relationship between class attendance and AF and KD scores can be seen in Figure 10. The poorer performance on either of these tests correspond to reduced class attendance, especially among AF scores. The results of these plots showcase that with the current sample of participants (n=15) RTL time is not affected, alone, by each score. The preliminary regression suggests that considering all other behaviors there is some statistically significant relationships that would benefit from further exploration in a study with a larger sample size.

The bubble plots in Figure 11 show soft trends in that participants who scored higher on NPC or had lower AF scores, generally chose to pursue academic accommodations to aid their recovery. Furthermore, the NPC and AF plots showcase that for students who score around the same on each test, those who choose to take accommodations within the classroom generally have shorter RTL times. The range of KD scores were about the same between students who chose accommodations and those who didn’t but showcase that for those who did choose to take classroom accommodations, RTL was shorter. In other words, these results suggest that if the participant who didn’t choose to take accommodations decide to do so, their RTL would have been expected to be shorter, as seen in a peer who scored similar but took accommodations. It is worth noting that participants did not know what their score was and how it performs against normative data for individuals without a concussion. Although the plots show the differences in participants with normal and prolonged recovery, little can be drawn from observations in these groups differences due to the limit in participants within the prolonged bucket. The same can be said for differences in the dichotomized oculomotor scores (low is below the reference line); there is generally an equal split in bubble size (RTL time) above and below the cluster cutoff (reference line), and matches the result of the scatterplots, again confirming that oculomotor scores alone (no behavioral variables) cannot prognosticate RTL in our data. Lastly, the simple dotplot of RTL time and choice to take accommodations begins to show a trend that the use of academic accommodations can reduce RTL time and are an important factor in management of a concussion in collegiate students. This further suggest the need for better guidance for selection, based on their symptoms, to improve overall classroom experience not hinder recovery time.

Combining these supplemental result in the plots and the paired t-test, with the regression data and the mixed effects model, we can begin to see trends within the use of oculomotor scores as components to be used in a RTL plan. The preliminary significance of the oculomotor scores on RTL time suggest that with a larger cohort of data, these scores could predict when one is ready to return to the classroom. The paired t-test show that there is a significant difference in pre-RTL AF and KD scores compared to post-RTL scores, showcasing the use of these scores as markers of readiness to return to academic stimuli. Furthermore, the simple dotplot of RTL time and choice to take accommodations begins to show a trend that the use of academic accommodations can reduce RTL time and are an important factor in management of a concussion in collegiate students. This further suggests the need for better guidance for selection of accommodations, based on their symptoms, to improve overall classroom experience. However, the limitations in sample size and the loss of significance in the binary regression models, showcase that these relationships between oculomotor scores and RTL time should be explored further to better understand how the scores can prognosticate recovery time. Furthermore, additional analyses should be explored that eliminate the need of averaging a subject's daily behaviors in order to create a model that contains continual daily behavior data.

5.3 RTL Policy Implications and Recommendations

Based on this research study, there are several policy implications for development of RTL procedures and policies including creation of point personnel for RTL management, improved education practices for all individuals involved in care, changes to the role an AT/medical professional plays in RTL, and development of a protocol for RTL. The implications suggested in this section are based on previous literature, as well as the analysis completed among student athletes and the DSO at RIT.

5.3.1 Create a Point Person Staff Role

One of the largest recurring themes expressed from the student-athletes and the DSO coordinator was the improvement of the time it takes to receive academic accommodations. Furthermore, the desire of better communication between the medical and academic side of individuals involved in managing the recovery of the concussed individual was also expressed. Additionally, many literature sources identify the desire of a point person for coordination of RTL management, to ensure recovery is progressed properly.[20,43] Literature suggests that RTP should not progress before a RTL protocol has been completed, and further suggests the need of improved communication and management of the concussion between academic and athletic recovery.[2,19,22,77] The current NCAA concussion safety protocol states that “unrestricted return-to-sport should not occur prior to unrestricted return-to-learn for injuries occurring while the athlete is enrolled in classes”, however, loose definitions of the term “unrestricted” makes it difficult to decide when a student can progress through the RTP protocol based on RTL recovery, and supports a need for improved education and implementation of RTL and RTP together with both academic and medical proffesionals.[77] Furthermore, RTL has not been at the forefront of care, and is still limited on a proper protocol and implementation strategies beyond providing injured students with the option to obtain accommodations. Without the use of a point person, whose role is to obtain recovery information from both the academic management plan and the athletic management plan, it is difficult for the athletic team to know how a student is managing their RTL. The introduction of a point person would allow for better communication between care teams, and ensure proper accommodations are provided for evolving symptom prevalence and resolution.

Introduction of a point person can further manage communication with a student's faculty and staff to ensure the requested accommodations can be implemented to reduce anxiety amongst the students. Furthermore, if this point person is trained in recognizing both the medical side of concussion recovery as well as the management of a concussion from the academic (DSO) side, this point person can ensure RTL and RTP protocols are implemented concurrently. Additionally, the point person can be used as an additional resource to educate the injured student on the challenges they could face both cognitively and physically during their recovery and can guide them on important behaviors to avoid or partake in to aid recovery.

Given the findings in literature and perspectives from students and the DSO, an introduction of a point person on campus would improve time to receive accommodations and ensure that proper recovery is managed. The introduction of a point person to manage both the student and student-athlete concussion would allow more resources to be dedicated to the recovering student, providing an additional resource and more bandwidth to the DSO and medical staff to dedicate to individual recovery plans. Successes of point personnel can be seen with the current staff member within RIT athletics who coordinates student-athlete academic success, a position added in February 2022. Since the introduction of her role within athletics, student-athletes have had access to additional tutoring, workshops, and support for managing and making academics a priority while also being successful in their sport.

In order to manage the recovery of both the non-athlete student and student-athlete, I would suggest the addition of a new role/staff member within the university who would work with all students. This person would communicate with the DSO to coordinate academic accommodation approval and management with professors, and medical staff (AT for student-athletes and the Student Health Center or diagnosing physician for non-athlete students) for physical (RTP) recovery. Potential barriers to having a designated point person is an addition of conflicting recommendations or ideas for management, or the crossing of lines among expertise and recommendation. Furthermore, this would require universities to add additional staff that they may not have the budget for and would likely require a high degree of training in order to successfully manage both the logistical academic side as well as the medical side of recovery. It would take a very specialized person to be successful in this role to track and manage recovery to guide accommodation selection and RTL progression.

5.3.2 AT Guides Accommodations Recommendation

As identified by the DSO coordinator interviewed in this study, accommodation guidance and selection for concussed students is based off her experience with working with concussed students for many years, the accommodations that have been most selected for certain symptoms throughout her time in the role. However, there is little guidance on the actual appropriate accommodations to choose for a student, based on their symptoms, and is often just a “shot in the dark” based on the academic load and what they think may help. The perspectives from students and the DSO coordinator in this study, suggest that improved academic accommodation recommendations and selection could improve RTL recovery and reduce symptomology, allowing the brain to recover faster, reduce the anxiety of the student, and ensure academic success throughout recovery. Changing how academic accommodations are requested could not only improve the speed at which accommodations can be provided, but also increase the efficacy of DSO resources and improve student experience in the classroom following a concussion. The current accommodation pathway does not include any input from medical professionals or quantitative symptom or neurocognitive functional data for the selection of accommodation; it solely relies on the student expressing symptomology and academic load. Proposed changes include the use of the athletic trainers or medical professionals relationship with the athlete, insight on the physical limitations and symptoms, and the use of clinical oculomotor and neurocognitive testing, to suggest appropriate accommodations to support the student in the classroom. Optimistically, the request for direct accommodations coming from the AT or medical personnel could expedite the accommodation process and provide more legitimacy and trust for professors that the requested accommodations are appropriate for their recovery. Similar testing among the non-athlete student population through the student health center, or trained point person, would serve the same benefits mentioned above for the student-athlete. Using the data from this study on oculomotor performance, normative data for these exams and other neurocognitive tests in concussion care, as well as behavioral data findings and exit survey themes can be utilized by medical professionals to suggest appropriate evidence-based accommodations for the student to the DSO to coordinate recovery based on cognitive performance, symptoms, and course load. In order to combat legal challenges, like HIPAA, it would be important that students sign waivers and approve the communication line from the medical professionals, point person, and academic staff about the student's injury and recovery plan. A summary of the use of symptoms and oculomotor data to guide accommodation selection can be found in Table 10.

Table 10. Evidence Based Academic Accommodation Recommendations

Marker/Symptom	Modification/Accommodation Option
Headaches	Additional Time on Assignments/Exams, Excused Absences (Early-Stage Recovery), Frequent Academic Breaks, Limit Screen Time, Rest, Light Aerobic Exercise, Moderate Caffeine Intake,
Difficulty Concentrating	Note Taker, Frequent Academic Breaks, Additional Time on Assignments/Exams, Taking Exam in Quiet Room, Decreased Workload, Excused Absences (Early-Stage Recovery), Rest, Moderate Caffeine Intake, Reduction in Music Listened To, Physical Activity (Symptom Limited)
Dizziness/Vestibular Disturbances	Excused Absences, Audio Lectures, Headphones in Class, Limit Screen Time, Limit Physical Activity, Rest, Ear Plugs
Sensitivty To Light	Limit Screen Time, Paper Notes, Reduce Screen Brightness, Wear Sunglasses in Class, Rest, Physical Activity (Symptom Limited)
Anxiety	Additional Time on Assignments/Exams, Frequent Academic Breaks, Taking Exam in Quiet Room, Excused Absences (Early-Stage Recovery), Reduction in Music Listened To, Rest
Fatigue	Additional Time on Assignments/Exams, Decreased Workload, Frequent Academic Breaks, Excused Absences (Early-Stage Recovery), Physical Activity (Symptom Limited), Rest
Poor Accommodative Facility Scores	Note Taker, Audio Lecture Recordings
Poor King Devick Scores	Additional Time on Assignments/Exams
Poor Near Point Of Convergence	Limit Computer Use, Audio Lecture Recordings, Increase Font Size, Additional Time on Assignments/Exams
Math Heavy Courses	Frequent Academic Breaks, Additional Time on Assignments/Exams, Decreased Workload, Excused Absences (Early-Stage Recovery)

5.3.3 Educate the Care Team

Proper care cannot be taken if the care team (DSO coordinator, point personnel, academic counselor, instructors, administrators, coaches, and the student) do not fully understand the challenges of physical and cognitive loads following a concussion. By providing training for concussion signs, symptoms, injury sequalae, and physical and cognitive implications for the student, academic personnel, coaches, DSO coordinators, and even the medical team, the care team can better understand the appropriate management of the injury and be able to better recognize where a student may still be facing challenges throughout their recovery. Furthermore, improved education around concussion can better inform students, coaches, teammates, and academic personnel the signs of a concussion to prevent danger to students and student athletes who may not think they have one. Through education the care team can better understand appropriate recommendations for care, given their symptoms, both in daily behaviors as well as appropriate accommodations, as suggested by the quantitative evidence from this study. A summary of the use of symptoms and oculomotor data to guide accommodation selection can be found in Table 10.

In addition to education around concussion and concussion care, it is also important to educate university students on the resources available to them if they suffer a concussion or suspect a head injury and need medical advice. Each year the RIT NCAA student athletes are provided educational materials about concussion and are provided with the knowledge to speak to athletic trainers if they receive a blow to the head or body that may result in a concussion, even if it occurs outside of their NCAA sanctioned sport (motor vehicle accident, off-season practice/game/leisure sport). Furthermore, all athletic training staff (including student employees) are trained in recognizing a concussion and concussive symptoms in order to properly diagnose a concussion and place an athlete in recovery protocol. However, the non-athlete student population who are not educated directly though the university, may lack the knowledge of resources like academic accommodations through the DSO that are available to them. It is suggested that all students be provided with educational material on the signs, symptoms, and recovery resources available to them if a concussion is expected, especially among students who partake in intramural or club sports, utilize the gym facilities, or work on campus in roles that put them at risk of head injury.

Lastly, providing similar training and education to instructors on campus can also ensure that any student who received care outside of the university (personal physician, urgent care, etc.) and asks for assistance directly from the instructor during recovery, can be informed of the available recovery accommodations and support from the DSO fand the student health center following their injury. Furthermore, this education and training can also assist university staff and faculty to recognize an injury among students, who may not realize they are suffering from an injury to the head but is having unexplained physical and cognitive difficulties. Education of academic staff and students could be coordinated by the point personnel hired to manage communication and recovery between academic and medical staff.

5.3.4 Introduce a RTL Protocol As University Policy

Like return-to-sport, RTL should be protected by a policy mandating proper protocols are followed to ensure care of the student is managed. To ensure proper management is taken among both non-athlete students and student athletes, the data presented here and within other literature suggest a required written RTL policy. From the data analysis and literature recommendations, the proposed RTL protocol guidelines are outlined below:

5.3.4.1 Behavior Management

Previous literature and consensus statements suggest that proper rest immediately following the injury (24-48 hours post-injury) is important for recovery. Current practices in RTP further suggest this rest period as a critical recovery period that should also be implemented for cognitive tasks. Further supported in common trends among students involved in this study, rest was a beneficial factor, identified both qualitatively and quantitatively throughout this work. This initial period of rest would ideally provide the point person enough time to begin the academic accommodation approval process with the DSO office, the students professors, and academic advisor. the role of the point person becomes important to ensure communication between the student and the professors, during this initial stage, to inform the professor the student will not be in class and will need accommodations is important to ensure the student is not penalized for missing class, exams, or assignments, during the initial stages of recovery.

Trends among behaviors and symptomology suggest the use of guidelines for daily activities among the students during this acute stage of recovery. Recommendations could look like guidelines on reducing caffeine and alcohol consumption, removing screen time and time spent listening to music, and receiving support for excused absence from class.

5.3.4.2 AF and KD Scores

Preliminary trends in the oculomotor scores (paired t-test and scatterplots) show that AF and KD could be useful tools in determining, quantitatively, when individual steps in RTL can occur. The established clinical cutoff values (k-means clusters) can be used to identify the challenges a student may face in the classroom. Students who perform poorly on the AF exam, will likely find it difficult to take notes in class, as this task requires repetitive switching of sight between their means of notetaking (near object) and the board at the front of the classroom (far object). Poor performance on AF testing suggests the need to limit class attendance until scores are above the cutoff value, indicating improved performance throughout recovery or the increase in ability to transition sight without an increase in symptomology. Throughout reintroduction to the classroom (including during excused absences), accommodations like an assigned note taker, or audio lectures would be beneficial to the student's academic performance during recovery and should be implemented into their individualized RTL strategy. Once symptoms no longer persist during this activity unrestricted return to the classroom can begin. Students who perform poorly on the KD exam, will likely find it challenging to complete reading and writing assignments, as this task requires the repetitive, saccade and comprehensive ability. Poor performance on this exam suggests the need to limit or extend time on assignments and reduce work related to reading until scores are below the clinical cutoff value, indicating improved reading and processing time. Once performance has improved, students can begin to reintroduce reading assignments into their daily activity. Once symptoms no longer persist during this activity unrestricted work that involves reading can begin.

5.3.4.3 Math Based Courses

Recurring findings on the difficulty of math-based courses among various cohorts of students (primary school, secondary school, collegiate students, and now collegiate student-athletes) showcase the need for RTL guidelines to aid recovery[18,26,71]. These findings indicate the need of a RTL progression among these courses, utilizing a combination of excused absences, additional time on assignments and exams, and frequent rest breaks. Students in these courses should not return to the class, unrestricted, until math-based work can be completed for at least the duration of the course, without frequent rest breaks and increase in symptomology. To support these students to be able to not fall behind in the class, and increase anxiety, students should be provided with a notetaker, additional time on assignments and exams, and the ability to obtain a tutor or time outside of class to meet with the instructor to obtain information and help, as needed. As the student begins to transition into being able to complete math-based work for longer periods of time (>30 min), the student could begin transitioning back to class, taking rest breaks every 30 minutes, and continuing to receive notes and additional time on work, until the math based academic tasks and class attendance can occur for the entire class time without an increase in symptomology. Similar steps can be taken for courses in which the individual student is having the most difficulty.

5.3.4.4 Screen Time

Quantitative data from this study and previous literature, as well as anecdotes among the student-athlete studies, showcase the impact screen time has on symptomology. This data suggests that RTL guidelines should recommend the limit of screen time to complete assignments and recreational use. Accommodations like paper assignments, altering note taking methods, and limiting behaviors of watching tv or spending time on social media should be recommended for the student. Students who are enrolled in online courses should be able to receive accommodations like excused absence from class until screen time can be tolerated, implementing frequent rest breaks as a transition/progression is implemented. Furthermore, these students could be allowed to only participate by listening and be provided a notetaker to ensure material can be referred to, to complete assignments. Students could also be allowed to take an exam in person, in order to prevent looking at a screen for long periods of time.

5.3.5 Making the Recommendations Successful

For recovery to be implemented successfully, it is important to garner support from the university to adopt this policy, in order to ensure adherence to the strategy without academic repercussions from faculty for students missing class, especially during the first stage of recovery when accommodations are still being approved and implemented. Furthermore, the role of the point person becomes important to ensure communication between the student and the professors, to inform the professor the student will not be in class and will need accommodations. This is important to ensure the student is not penalized for missing class, exams, or assignments, during the initial stages of recovery, reducing anxiety about falling behind and ensuring the student is provided support for managing their injury.

Additionally, this point person will play an important role in gathering symptomology throughout class time for each student and managing progression of the protocol. It is also recommended that the point person meet with the student every few days to adjust appropriate accommodations, and address any challenges the student may be facing, that they were not facing prior. This point person could also be trained in performing the oculomotor tests or other neurocognitive testing and gather data to see how the student is progressing through recovery and would be ready to progress back to class. Lastly, this point person would also be in charge of informing medical personnel on progression status for proper integration with the RTP protocol, and among academic staff when changes need to be made.

If adopted as university policy, anxiety and stress around missing class, assignments, or exams would optimistically improve symptomology and recovery of the student to get them back to class sooner, during the later stages of their recovery, as well as allowing for proper adjustment of daily behaviors to reduce symptomology. Adoption of this protocol by the university would allow for a more structured process of return that can be customized to each individual student and the challenges they are facing, to ensure appropriate accommodations are selected for their course load. Lastly, the unrestricted RTP protocol should not begin until the student has returned to the classroom and no longer needs accommodations to complete academic tasks.

5.4 Study Strengths, Limitations, and Implications for Future Research

5.4.1 Strengths

To our knowledge, this is only the second study to use text messaging to collect symptom data as frequently as 4-times per day during RTL recovery.[18] The use of daily phone calls ensured comprehensive data could be collected from participants about their class attendance and daily behaviors by allowing for clarification of activities, if needed. The requirement of the 48-hour period of academic participation as the signal for completion of the study, and implemented RTL, allowed us to ensure tolerance to academic activity over a wider range of course load, and to limit any false positives. Furthermore, the symptomology and daily behaviors (class attendance) was not reported to the AT and did not inform their practice of guiding RTP, blinding the AT from the RTL side to prohibit influence on their decision for RTP progression. Lastly, the study presents preliminary evidence on the use of validated clinical assessments and quantitative symptom data to prognosticate RTL and guide evidence-based academic accommodation selection, corroborating results in a cohort of non-athlete college students from a larger, public institution, in a different region of the US, while also presenting new findings and trends.

5.4.2 Limitations

There were a few limitations associated with the methodology of this study. First, the small sample size (n=15) limits the range of courses (major, difficulty, level of study), and the student perspectives of course difficulty. Furthermore, as mentioned earlier, the small sample size limited the ability of the data to prognosticate RTL but suggests the need for further studies to be performed, gathering data from a larger sample size, while still using the methods in this study.

Additionally, the small sample size limits the generalizability of the study but can be used as a second source of findings to build RTL recommendations. Furthermore, although this study focuses on student-athletes, our discoveries will undoubtedly relate to all university students recovering from concussion. Second, the small sample size and skewness of most symptom severities resulted in non-normal data, which had to be transformed to be used in a mixed effects model. Third, the criteria for recovery required return to two consecutive days of class participation. This criteria could delay "recovered" status due to no classes on a certain day, or the weekend. Fourth, the use of text messages to gather symptom reports exposed participants to screen time, which could potentially increase symptomology. However, the availability of students to answer these four daily symptom questionnaires would have been limited without the use of technology. Fifth, to keep the diagnosing athletic trainers unbiased in their practice, the participants medical recommendations or provider referrals (e.g., vestibular therapy, medication, RTP progression) were not tracked, but could have potentially influenced participant behavior.

5.4.3 Implications for Future Research

For further research, it is suggested that studies further analyze populations of concussed students, on a larger cohort, including both students and student-athletes, and enlisting the help of university health centers and sports medicine teams. Furthermore, a cross-university sample would allow for understanding of differences in academic accommodation pathways, implementation, and educator perspectives. Larger sample sizes would permit discussion around correlation between behaviors and symptoms, as well as provide more data on the use of oculomotor scores to prognosticate RTL. Another avenue of research could use a controlled trial experiment to see if a concurrent RTL and RTP management plan, using the graduated strategies in this paper, result in better outcomes for student-athletes recovering from a concussion. This would require a longitudinal study that follows students from initial diagnosis through each stage of recovery. Although challenging to watch every step, the use of a point person to oversee this management would ensure that communication between all individuals involved in the care could ensure that the proper stage of each plan is implemented.

Eventually, the behavior-symptom data and oculomotor performance would be intended to provide medical staff with evidence-based guidance for implementation of the RTL/RTP graduated strategy for concussion treatment. The relationships identified in this study corroborate earlier findings and provide further preliminary evidence, however, limit the robustness of utilizing these parameters to solely guide recovery, at this time.

6. Conclusion

This research study presents preliminary data on the types of behaviors that influence concussion symptoms and recovery timeline, corroborating findings from studies performed on younger (K-12) students and their predictions of effects in collegiate students. The use of accommodations, based on symptomology and oculomotor performance, and reducing negative behaviors that limit healing of the brain can be utilized to improve recovery time. Lastly, the study of current RIT policies and practices among both student-athletes and general students in managing academic return from a concussion identified areas of improvement within the care of collegiate concussion. Policy changes surrounding the introduction of a point person to manage return to learn, the use of medical professionals in recommending accommodations, improved education and management, and the introduction of university policies and RTL protocols are suggested. This preliminary data is only the beginning in suggesting recommendations for proper collegiate RTL policies. As larger studies are completed these policies will have to be updated and should become more aligned with RTP protocols and the growing field of concussion care.

7. References

1. Frieden TR, Houry D, Baldwin G. *Report to Congress on Traumatic Brain Injury Epidemiology and Rehabilitation | Concussion | Traumatic Brain Injury | CDC Injury Center*.; 2015. Accessed August 25, 2022. https://www.cdc.gov/traumaticbraininjury/pubs/congress_epi_rehab.html
2. McCrory P, Meeuwisse W, Dvořák J, et al. Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. *Br J Sports Med*. 2017;51(11):838-847. doi:10.1136/BJSPORTS-2017-097699
3. Giza CC, Hovda DA. The new neurometabolic cascade of concussion. *Neurosurgery*. 2014;75:S24-S33. doi:10.1227/NEU.0000000000000505
4. Romeu-Mejia R, Giza CC, Goldman JT. Concussion Pathophysiology and Injury Biomechanics. *Curr Rev Musculoskelet Med*. 2019;12(2):105-116. doi:10.1007/S12178-019-09536-8/FIGURES/1
5. Graham R, Rivara FP, Ford MA, et al. Sports-Related Concussions in Youth. *Sports-Related Concussions in Youth*. Published online February 4, 2014. doi:10.17226/18377
6. Davies S, Bird B. Motivations for Underreporting Suspected Concussion in College Athletics. *J Clin Sport Psychol*. 2015;9(2). Accessed August 25, 2022. https://ecommons.udayton.edu/edc_fac_pub/44
7. Breck J, Bohr A, Poddar S, McQueen MB, Casault T. Characteristics and Incidence of Concussion Among a US Collegiate Undergraduate Population. *JAMA Netw Open*. 2019;2(12):e1917626-e1917626. doi:10.1001/JAMANETWORKOPEN.2019.17626
8. Tator CH. Concussions and their consequences: current diagnosis, management and prevention. *CMAJ*. 2013;185(11):975-979. doi:10.1503/CMAJ.120039

9. Rose SC, Weber KD, Collen JB, Heyer GL. The Diagnosis and Management of Concussion in Children and Adolescents. *Pediatr Neurol*. 2015;53(2):108-118. doi:10.1016/J.PEDIATRNEUROL.2015.04.003

10. Broglio SP, Cantu RC, Gioia GA, et al. National Athletic Trainers' Association Position Statement: Management of Sport Concussion. *J Athl Train*. 2014;49(2):245-265. doi:10.4085/1062-6050-49.1.07

11. Powell JW. Cerebral Concussion: Causes, Effects, and Risks in Sports. *J Athl Train*. 2001;36(3):307. Accessed August 25, 2022. /pmc/articles/PMC155423/

12. Washington State Legislature. *Zackery Lystedt Law*. Washington State; 2009. Accessed August 25, 2022. https://apps.leg.wa.gov/rcw/default.aspx?cite=28a.600.190

13. O'Neill JA, Cox MK, Clay OJ, et al. A review of the literature on pediatric concussions and Return-to-Learn (RTL): Implications for RTL policy, research, and practice. *Rehabil Psychol*. 2017;62(3):300-323. doi:10.1037/REP0000155

14. Pachman S, Lamba A. Legal Aspects of Concussion: The Ever-Evolving Standard of Care. *J Athl Train*. 2017;52(3):186-194. doi:10.4085/1062-6050-52.1.03

15. Broglio SP, Collins MW, Williams RM, Mucha A, Kontos AP. Current and emerging rehabilitation for concussion. A Review of the evidence. *Clin Sports Med*. 2015;34(2):213-231. doi:10.1016/j.csm.2014.12.005

16. McGrath N. Supporting the Student-Athlete's Return to the Classroom After a Sport-Related Concussion. *J Athl Train*. 2010;45(5):492-498. doi:10.4085/1062-6050-45.5.492

17. Carson JD, Lawrence Md DW, Kraft Md SA, et al. Premature return to play and return to learn after a sport-related concussion: Physician's chart review. *Canadian Family Physician*. 2014;60(6):e310. Accessed August 25, 2022. /pmc/articles/PMC4055342/

18. Bevilacqua ZW, Kerby ME, Fletcher D, et al. Preliminary evidence-based recommendations for return to learn: A novel pilot study tracking concussed college students. *Concussion*. 2019;4(2). doi:10.2217/CNC-2019-0004/ASSET/IMAGES/LARGE/FIGURE4.JPEG

19. Bevilacqua Z, Cothran DJ, Rettke DJ, Koceja DM, Nelson-Laird TF, Kawata K. Educator perspectives on concussion management in the college classroom: a grounded theory introduction to collegiate return-to-learn. *BMJ Open*. 2021;11(4):e044487. doi:10.1136/BMJOPEN-2020-044487

20. Bowman TG, Singe SM, Pike Lacy AM, Register-Mihalik JK. Challenges Faced by Collegiate Athletic Trainers, Part II: Treating Concussed Student-Athletes. *J Athl Train*. 2020;55(3):312-318. doi:10.4085/1062-6050-85-19

21. Childers C, Hux K. Invisible Injuries: The Experiences of College Students with Histories of Mild Traumatic Brain Injury. *J Postsecond Educ Disabil*. 2016;29(4):389-405.

22. NCAA Sport Science Institute. *Diagnosis and Management of Sport Related Concussion Best Practices*.; 2021.

23. Alexander DG, Shuttleworth-Edwards AB, Kidd M, Malcolm CM. Mild traumatic brain injuries in early adolescent rugby players: Long-term neurocognitive and academic outcomes. *https://doi.org/103109/0269905220151031699*. 2015;29(9):1113-1125. doi:10.3109/02699052.2015.1031699

24. Bailes JE, Petraglia AL, Omalu BI, Nauman E, Talavage T. Role of subconcussion in repetitive mild traumatic brain injury: A review. *J Neurosurg*. 2013;119(5):1235-1245. doi:10.3171/2013.7.JNS121822

25. Wasserman EB, Bazarian JJ, Mapstone M, Block R, van Wijngaarden E. Academic dysfunction after a concussion among US high school and college students. *Am J Public Health*. 2016;106(7):1247-1253. doi:10.2105/AJPH.2016.303154

26. Ransom DM, Vaughan CG, Pratson L, Sady MD, McGill CA, Gioia GA. Academic Effects of Concussion in Children and Adolescents. *Pediatrics*. 2015;135(6):1043-1050. doi:10.1542/PEDS.2014-3434

27. Heideman. The Effect Concussions Have on Grades. Jacksonville Orthopaedic Institute. Published 2021. Accessed August 25, 2022. https://www.joionline.net/trending/content/effect-concussions-have-grades

28. Corwin DJ, Zonfrillo MR, Master CL, et al. Characteristics of prolonged concussion recovery in a pediatric subspecialty referral population. *Journal of Pediatrics*. 2014;165(6):1207-1215. doi:10.1016/j.jpeds.2014.08.034

29. Arbogast KB, McGinley AD, Master CL, Grady MF, Robinson RL, Zonfrillo MR. Cognitive rest and school-based recommendations following pediatric concussion: The need for primary care support tools. *Clin Pediatr (Phila)*. 2013;52(5):397-402. doi:10.1177/0009922813478160

30. Darling SR, Leddy JJ, Baker JG, et al. Evaluation of the zurich guidelines and exercise testing for return to play in adolescents following concussion. *Clinical Journal of Sport Medicine*. 2014;24(2):128-133. doi:10.1097/JSM.0000000000000026

31. Stern RA, Seichepine D, Tschoe C, et al. Concussion Care Practices and Utilization of Evidence-Based Guidelines in the Evaluation and Management of Concussion: A Survey of New England Emergency Departments. *https://home.liebertpub.com/neu*. 2017;34(4):861-868. doi:10.1089/NEU.2016.4475

32. Gibson S, Nigrovic LE, O'Brien M, Meehan WP. The effect of recommending cognitive rest on recovery from sport-related concussion. *http://dx.doi.org/103109/026990522013775494*. 2013;27(7-8):839-842. doi:10.3109/02699052.2013.775494

33. Moor HM, Eisenhauer RC, Killian KD, et al. THE RELATIONSHIP BETWEEN ADHERENCE BEHAVIORS AND RECOVERY TIME IN ADOLESCENTS AFTER A SPORTS-RELATED CONCUSSION: AN OBSERVATIONAL STUDY. *Int J Sports Phys Ther*. 2015;10(2):225. Accessed August 25, 2022. /pmc/articles/PMC4387730/

34. Leddy JJ, Haider MN, Ellis M, Willer BS. Exercise is Medicine for Concussion. *Curr Sports Med Rep*. 2018;17(8):262-270. doi:10.1249/JSR.0000000000000505

35. Leddy JJ, Hinds AL, Miecznikowski J, et al. Safety and prognostic utility of provocative exercise testing in acutely concussed adolescents: A randomized trial. *Clinical Journal of Sport Medicine*. 2018;28(1):13-20. doi:10.1097/JSM.0000000000000431

36. Leddy JJ, Haider MN, Ellis MJ, et al. Early Subthreshold Aerobic Exercise for Sport-Related Concussion: A Randomized Clinical Trial. *JAMA Pediatr*. 2019;173(4):319-325. doi:10.1001/JAMAPEDIATRICS.2018.4397

37. Brown NJ, Mannix RC, O'Brien MJ, Gostine D, Collins MW, Meehan WP. Effect of Cognitive Activity Level on Duration of Post-Concussion Symptoms. *Pediatrics*. 2014;133(2):e299-e304. doi:10.1542/PEDS.2013-2125

38. Grubenhoff JA, Deakyne SJ, Comstock RD, Kirkwood MW, Bajaj L. Outpatient follow-up and return to school after emergency department evaluation among children with persistent post-concussion symptoms. *https://doi.org/103109/0269905220151035325*. 2015;29(10):1186-1191. doi:10.3109/02699052.2015.1035325

39. Millichap JG. Vestibular Deficits Following Concussion. *Pediatr Neurol Briefs*. 2015;29(5):35. doi:10.15844/PEDNEURBRIEFS-29-5-2

40. Baker JG, Leddy JJ, Darling SR, et al. Factors Associated with Problems for Adolescents Returning to the Classroom after Sport-Related Concussion. *Clin Pediatr (Phila)*. 2015;54(10):961-968. doi:10.1177/0009922815588820

41. Iadevaia C, Roiger T, Zwart MB. Qualitative Examination of Adolescent Health-Related Quality of Life at 1 Year Postconcussion. *J Athl Train*. 2015;50(11):1182-1189. doi:10.4085/1062-6050-50.11.02

42. Stein CJ, Macdougall R, Quatman-Yates CC, et al. Young athletes' concerns about sport-related concussion: The patient's perspective. *Clinical Journal of Sport Medicine*. 2016;26(5):386-390. doi:10.1097/JSM.0000000000000268

43. McAvoy K, Eagan-Johnson B, Dymacek R, Hooper S, McCart M, Tyler J. Establishing Consensus for Essential Elements in Returning to Learn Following a Concussion. *Journal of School Health*. 2020;90(11):849-858. doi:10.1111/JOSH.12949

44. Glang AE, Koester MC, Chesnutt JC, et al. The effectiveness of a web-based resource in improving postconcussion management in high schools. *Journal of Adolescent Health*. 2015;56(1):91-97. doi:10.1016/j.jadohealth.2014.08.011

45. Dreer LE, Crowley MT, Cash A, O'Neill JA, Cox MK. Examination of Teacher Knowledge, Dissemination Preferences, and Classroom Management of Student Concussions: Implications for Return-to-Learn Protocols. *Health Promot Pract*. 2017;18(3):428-436. doi:10.1177/1524839916650865

46. Hachem LD, Kourtis G, Mylabathula S, Tator CH. Experience with Canada's First Policy on Concussion Education and Management in Schools. *Canadian Journal of Neurological Sciences*. 2016;43(4):554-560. doi:10.1017/CJN.2016.41

47. Heyer GL, Weber KD, Rose SC, Perkins SQ, Schmittauer CE. High school principals' resources, knowledge, and practices regarding the returning student with concussion. *Journal of Pediatrics*. 2015;166(3):594-599.e7. doi:10.1016/j.jpeds.2014.09.038

48. Kasamatsu T, Cleary M, Bennett J, Howard K, McLeod TV. Examining Academic Support After Concussion for the Adolescent Student-Athlete: Perspectives of the Athletic Trainer. *J Athl Train*. 2016;51(2):153-161. doi:10.4085/1062-6050-51.4.02

49. Zirkel PA, Brown BE. K–12 Students With Concussions: A Legal Perspective. *Journal of School Nursing*. 2015;31(2):99-109. doi:10.1177/1059840514521465

50. Sarmiento K, Donnell Z, Bell E, Hoffman R. From the CDC: A qualitative study of middle and high school professionals' experiences and views on concussion: Identifying opportunities to support the return to school process. *J Safety Res*. 2019;68:223-229. doi:10.1016/J.JSR.2018.10.010

51. Halstead ME, McAvoy K, Devore CD, et al. Returning to Learning Following a Concussion. *Pediatrics*. 2013;132(5):948-957. doi:10.1542/PEDS.2013-2867

52. Mokris RL, Kessler A, Williams K, Ranney J, Webster J, Stauffer K. Assessing concussion knowledge and awareness in faculty and staff in a collegiate setting: *https://doi.org/101177/2059700219870920*. 2019;3:205970021987092. doi:10.1177/2059700219870920

53. One Hundred Fourteenth Congress of the United States of America. *Every Student Succeeds Act*. Congress; 2015.

54. Hoffman NL, O'Connor PJ, Schmidt MD, Lynall RC, Schmidt JD. Relationships between Post-Concussion Sleep and Symptom Recovery: A Preliminary Study. *J Neurotrauma*. 2020;37(8):1029-1036. doi:10.1089/neu.2019.6761

55. Xie L, Kang H, Xu Q, et al. Sleep Drives Metabolite Clearance from the Adult Brain. *Science (1979)*. 2013;342(6156):373-377. doi:10.1126/science.1241224

56. Turgeon C, Champoux F, Lepore F, Leclerc S, Ellemberg D. Auditory Processing After Sport-Related Concussions. *Ear Hear*. 2011;32(5):667-670. doi:10.1097/AUD.0b013e31821209d6

57. vander Werff KR, Rieger B. Auditory and Cognitive Behavioral Performance Deficits and Symptom Reporting in Postconcussion Syndrome Following Mild Traumatic Brain Injury. *Journal of Speech, Language, and Hearing Research*. 2019;62(7):2501-2518. doi:10.1044/2019_JSLHR-H-18-0281

58. Smith R, Layman D. The Use of Preferred Music to Improve the Sleep Quality of a High School Athlete with Post-Concussion Syndrome. *Music Ther Perspect*. 2022;40(1):111-113. doi:10.1093/mtp/miac007

59. Tornstrom K. Does caffeine treat or trigger headaches? Mayo Clinic Health System.

60. Mason BN, Russo AF. Vascular Contributions to Migraine: Time to Revisit? *Front Cell Neurosci*. 2018;12. doi:10.3389/fncel.2018.00233

61. Weber A. The Mechanism of the Action of Caffeine on Sarcoplasmic Reticulum. *Journal of General Physiology*. 1968;52(5):760-772. doi:10.1085/jgp.52.5.760

62. Bruce SE, Werner KB, Preston BF, Baker LM. Improvements in concentration, working memory, and sustained attention following consumption of a natural citicoline-caffeine beverage. *Int J Food Sci Nutr*. 2014;65(8):1003-1007.

63. Office of Dietary Supplements. Choline. National Institutes of Health.

64. Merritt VC, Padgett CR, Jak AJ. A systematic review of sex differences in concussion outcome: What do we know? *Clin Neuropsychol*. 2019;33(6):1016-1043. doi:10.1080/13854046.2018.1508616

65. Mollayeva T, El-Khechen-Richandi G, Colantonio A. Sex & gender considerations in concussion research. *Concussion*. 2018;3(1):CNC51. doi:10.2217/cnc-2017-0015

66. Bazarian JJ, Blyth B, Mookerjee S, He H, McDermott MP. Sex Differences in Outcome after Mild Traumatic Brain Injury. *J Neurotrauma*. 2010;27(3):527-539. doi:10.1089/neu.2009.1068

67. Broshek DK, Kaushik T, Freeman JR, Erlanger D, Webbe F, Barth JT. Sex differences in outcome following sports-related concussion. *J Neurosurg*. 2005;102(5):856-863. doi:10.3171/jns.2005.102.5.0856

68. Hillard J, Parisi T. Is Alcohol A Depressant? Addiction Center.

69. Casares-López M, Castro-Torres JJ, Ortiz-Peregrina S, Martino F, Ortiz C. Changes in Visual Performance under the Effects of Moderate–High Alcohol Consumption: The Influence of Biological Sex. *Int J Environ Res Public Health*. 2021;18(13):6790. doi:10.3390/ijerph18136790

70. Costanzo L. *Physiology*. Vol Sixth. Elsevier, Inc.; 2018.

71. Holmes A, Chen Z, Yahng L, Fletcher D, Kawata K. Return to Learn: Academic Effects of Concussion in High School and College Student-Athletes. *Front Pediatr*. 2020;8. doi:10.3389/fped.2020.00057

72. Yang Z, Yeo RA, Pena A, et al. An fMRI Study of Auditory Orienting and Inhibition of Return in Pediatric Mild Traumatic Brain Injury. *J Neurotrauma*. 2012;29(12):2124-2136. doi:10.1089/neu.2012.2395

73. Leddy JJ, Cox JL, Baker JG, et al. Exercise Treatment for Postconcussion Syndrome. *Journal of Head Trauma Rehabilitation*. 2013;28(4):241-249. doi:10.1097/HTR.0b013e31826da964

74. Niogi SN, Mukherjee P. Diffusion Tensor Imaging of Mild Traumatic Brain Injury. *Journal of Head Trauma Rehabilitation*. 2010;25(4):241-255. doi:10.1097/HTR.0b013e3181e52c2a

75. Mansur A, Hauer TM, Hussain MW, et al. A Nonliquid Crystal Display Screen Computer for Treatment of Photosensitivity and Computer Screen Intolerance in Post-Concussion Syndrome. *J Neurotrauma*. 2018;35(16):1886-1894. doi:10.1089/neu.2017.5539

76. Acord-Vira A, Curtis R, Davis D, Wheeler S. Returning to the Classroom Following Sport-Related Concussion: Perspectives of College Student Athletes. *J Postsecond Educ Disabil*. 2019;32(1):35-48.

77. NCAA Sport Science Institute. Concussion Safety Protocol Template - NCAA.org. Published 2022. Accessed August 25, 2022. https://www.ncaa.org/sports/2018/7/16/concussion-safety-protocol-template.aspx

Appendix A

The thirteen concussion RTL consensus statements from the National Collaborative on Children's Brain Injury (NCBI).[43]

1. Students recovering from a concussion often need an initial period of relatively greater cognitive and physical rest, the timing and specific nature of which will vary from student to student

2. An estimated 70% of students recover from a concussion in 28 days with a gradual reduction of symptoms.11 This supports a gradual return to social and cognitive activity at home and school over the first 4 weeks of recovery. The speed of re-introduction will vary and must be individualized

3. Numerous positive social and emotional benefits are gained by being at school, even during recovery from a concussion. Unless contraindicated by a serious medical complication, a student with a concussion should return to school/learn even before symptoms are 100% resolved, provided the student can manage fluctuating symptoms, and the school concussion management team has received education and resources to support the student in the educational setting

4. A concussion management team should include representatives from school academic, school physical/health services, medical, and family/student domains who work collaboratively to develop and adjust an individualized Return to Learn plan.

5. A family is advised to seek out medical evaluation, specifically, a timely medical evaluation, treatment, and clearance for each concussion (regardless of the age of the student or the mechanism of injury)

6. Academic adjustments written into the Return to Learn plan are best overseen and directed by school professionals with dedicated expertise and knowledge of educational law, policy, and curriculum, guiding a collaborative Return to Learn process among the members of the concussion management team

7. Progress monitoring should include symptom monitoring, no less than one time per week

8. Progress monitoring should include academic monitoring, no less than one time per week

9. Schools have existing educational safeguards to support all students who struggle academically, medically, psychologically, and socially at school. Concussion can be included and managed using the existing educational safeguards

10. Schools should provide increasing tiers of academic support for the students with concussions that do not resolve in a typical timeframe

11. Schools may apply their existing tiers of support for students with concussion and need not delay or postpone academic supports while awaiting community health care input if medical input is not timely or available

12. Data from a neuropsychological evaluation, is not required, but can be helpful and should be considered and may be incorporated into a Return to Learn plan if available

13. Existing educational safeguards exist for students, although they are little known and underutilized for concussion. They are prompt, flexible, and systematic for all concussed student athletes and non-athletes with academic needs. Return to Learn can be robust, widespread, systematized, and sustainable if embedded into existing educational frameworks