Program Evaluation of a New Initiative in an Interdisciplinary Pediatric Concussion Clinic: Active Rehabilitation Following Sports Concussion

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Program Evaluation of a New Initiative in an Interdisciplinary Pediatric Concussion Clinic:

Active Rehabilitation Following Sports Concussion

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Author Note

We have no known conflict of interest to disclose.

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Abstract

Mild TBI or concussion is a growing public health concern in adolescents, and early interventions should target persistent symptoms that can impact learning, behavior, and emotions. The past decade has brought increased awareness, identification, and reporting of concussion and an accompanying explosion of quality research on the management of concussion. The overwhelming theme that has emerged is active rehabilitation which challenges the long-standing recommendation of rest and restriction.

This comprehensive program evaluation has focused on a new initiative in a pediatric interdisciplinary brain injury clinic, including an analysis of the impact of active rehabilitation on athlete concussion recovery. The W.F. Kellogg Model for Program Evaluation was used as a guide to provide stakeholders with a summary of successes and challenges of clinic processes including the implementation of treadmill testing in this specialty clinic. This evaluation supports that the clinic model for active rehabilitation is evidence-based and impactful. Recommendations include developing strong community partnerships with a goal of integrating active rehabilitation into community clinics and schools where it can improve outcomes for thousands of adolescents, including those at highest risk for persistent symptoms and poor outcomes.

Keywords: concussion, mild traumatic brain injury, sports-related concussion, active rehabilitation, exercise therapy, program evaluation.
Program Evaluation of a New Initiative in an Interdisciplinary Pediatric Concussion Clinic

Traumatic brain injury (TBI) is a leading cause of pediatric morbidity and mortality and a growing public health concern, with over 812,000 emergency department visits annually in children under 15 years of age (Centers for Disease Control & Prevention, 2019). TBI is categorized as mild, moderate, or severe with mild TBI (mTBI) accounting for 75% of reported injuries in the United States (Lumba-Brown, et al., 2018a). The true burden of mTBI is difficult to capture, with the majority of mild injuries evaluated in clinic or urgent care settings, and many more that go untreated (Lumba-Brown et al., 2018a; Shen et al., 2020). The terms mTBI and concussion are often used interchangeably, but mTBI is an umbrella term for injuries that are not life-threatening. This includes complicated mTBI with intracranial hemorrhage or other structural changes on neuroimaging as well as concussion (Lumba-Brown et al., 2018; Lumba-Brown et al., 2018a). According to the Centers for Disease Control and Prevention (2021), mTBI involves a bump, blow, or jolt to the head or body that causes the brain to move rapidly back and forth within the skull. These forces lead to chemical changes in the brain and stretching or damage to brain cells. The accompanying changes in brain function are temporary in the majority of patients, but a subset of children will have persistent symptoms that can affect physical, cognitive, and psychological functioning long after TBI pathophysiology has resolved (Lumba-Brown et al., 2018). Mild TBI needs to be addressed with evidence-based care to decrease the risk for persistent symptoms and long-term health problems that can impact learning, behavior, and emotions (Sarmiento et al., 2014; Centers for Disease Control and Prevention, 2021). TBI outcomes may be impacted by health disparities, and evidence-based care must also consider at-risk populations (Jimenez et al., 2020; Goreth, 2017).

Mild TBI and Vulnerable Populations

Vulnerable populations are social groups who experience diminished resources and subsequent high risk for poor outcomes. These groups suffer social injustice and include children, females, people of
color, people with disabilities, and socioeconomically disadvantaged families across the U.S. and the globe (Levy, 2019). A population-based focus and framework that addresses vulnerable groups is integral in terms of research implications and interventional and outcome studies (Flakerud & Winslow, 1998) and these factors were considered in the development of this project. Early interventions to manage mTBI should target at-risk populations to improve quality of life and overall population health (Goreth, 2017). Predictors of poor quality of life following mTBI were examined in a prospective cohort study of children under 18 years of age, and authors measured change in validated quality of life indices at three months and 12 months following injury (Zonfillo et al., 2014). Poor functioning was defined as a score of less than 15 from baseline based on a validated measure of physical, emotional, social, and school functioning called the PedsQL. Results indicated that Hispanic ethnicity, Medicaid insurance, low household income, and less parental education are significant risk factors for poor functioning (Zonfrillo et al., 2014). Holmes et al. (2016) explored the relationship between socio-demographics on cognitive-related symptoms following sports concussion. Results suggest that racial disparities exist in this setting, and Black children are more likely to suffer cognitive-related symptoms relative to White children.

Jimenez et al. (2013) compared the degree of disability in functioning after TBI between Hispanic and non-Hispanic white (NHW) children in a prospective cohort study of children under 18 years of age. Results showed that Hispanic children with all severities of TBI suffered greater decline from baseline in quality of life indicators compared with NHW children (Jimenez et al., 2013). Jimenez et al. (2020) went on to explore the experiences of Hispanic families following hospital discharge for TBI. This qualitative study found that Hispanic parents, especially those with limited English proficiency encounter substantial challenges in accessing outpatient therapies and school resources. Consistently disaggregated data collection and further research are needed to better understand health disparities in race, ethnicity, and socioeconomic status (Gigli, 2021) and the impact on vulnerable population outcomes in mTBI.
Sports-Related Concussion

Sport-related concussions (SRC) are the most common type of mTBI with an estimated 1.6 million to 3.8 million sport-related TBIs annually in the U.S. (Centers for Disease Control and Prevention, 2007). Adolescents are more vulnerable to mTBI than adults (Shen et al., 2020; Sarmiento et al., 2014), and 15% of all U.S. high-school students self-report at least one sports or recreation-related concussion in the past 12 months (Centers for Disease Control and Prevention, 2021a). SRC occurs commonly in both helmeted and non-helmeted sports with boys’ football and girls’ soccer having the highest and second-highest rates respectively (Kerr et al., 2019). Increased awareness, identification, and reporting of SRC in the past decade have contributed to increasing rates of concussion and decreasing rates of recurrent injury (Harmon et al., 2013; Kerr et al., 2019). Scientific advances in concussion pathophysiology have led to organizational and government advocacy for standardized protocols for side-line evaluation and removal from play (McAllister & McCrea, 2017). Following the 2003 CDC Heads Up initiative to inform action for concussion prevention, recognition, and response, all 50 states have passed legislation to address concussion management in youth athletics (Centers for Disease Control and Prevention, 2015). The science and legislation surrounding SRC consistently support concussion education, with a goal of removing athletes from play and ensuring proper medical evaluation prior to return to the field (Centers for Disease Control and Prevention, 2020). However, the evidence to guide concussion management beyond removal from play has been limited until recent years. There is now a growing body of research to guide concussion treatment including Level I evidence, which has enhanced but also contradicted expert consensus statements and observational studies that shaped past clinical care.
Summary of the Healthcare Need

TBI is a leading cause of death and disability in children and mTBI accounts for the large majority of injuries (Centers for Disease Control and Prevention, 2019; Lumba-Brown et al., 2018). Mild TBI or concussion is a growing public health concern for children and adolescents, and early interventions should target persistent symptoms that can impact learning, behavior, and emotions. The past decade has brought increased awareness, identification, and reporting of concussion and an accompanying explosion of quality research on the management of concussion. The overwhelming theme that has emerged is active rehabilitation which challenges the long-standing recommendation of rest. The literature review that follows will provide the background followed by a targeted search and analysis of Level I and II evidence that examines the potential benefit of physical activity during acute concussion recovery.

Literature Review

Framework & Background

The John Hopkins Nursing Evidence-Based Practice (EBP) Model was used as a framework to develop the literature review with the goal of using a scientific process to translate evidence into practice (Dang & Dearholt, 2018). This problem-solving approach began with a critical examination of past body of knowledge which was based on expert opinion and consensus statements. The traditional goal of concussion management is to prevent further injury during the acute period when the brain is believed to be in a vulnerable state (Leddy et al., 2016, Lumba-Brown et al., 2018). For this reason, the cornerstone of concussion treatment has been rest and restriction until symptoms resolve (Guthrie, 2017; Lumba-Brown et al., 2018; Willer et al., 2019). While many children recover fully within four weeks, 20-30% of children will experience persistent post-concussion symptoms (PPCS) which is defined by symptoms greater than 28 days, and can significantly impact quality of life (Calloway & Kosofsky,
2019; Leddy et al., 2018; Leddy et al., 2019; Leddy et al., 2021). In 2016, the International Concussion in Sport Group published a consensus statement noting that there was a paucity of evidence that complete rest augments recovery or prevents PPCS (McCrory et al., 2017). In 2018, the Centers for Disease Control and Prevention (CDC) provided the first comprehensive guideline for the diagnosis, prognosis, and management of mTBI in children based on a systematic review of the literature (Lumba-Brown et al., 2018). Recommendations for physical activity are conservative, but authors note that inactivity beyond three days may exacerbate self-reported symptoms. Evidence-based concussion literature now consistently supports that rest beyond 48-72 hours following SRC is not beneficial and may lead to persistent symptoms (Thomas et al., 2015; Grool et al., 2016; Leddy et al., 2016; Leddy et al., 2019; Leddy et al., 2021; Willer et al., 2019). Current data suggests that autonomic nervous system (ANS) dysfunction accounts for many concussion symptoms, and graded exercise as treatment in the first week is shown to improve ANS dysfunction and speed recovery (Calloway & Kosofsky, 2019; Leddy et al., 2016; Leddy et al., 2018; Leddy et al., 2019; Willer et al., 2019; Leddy et al., 2021).

Rest Versus Active Rehabilitation

The John Hopkins EBP Model was used to approach the targeted literature review with a focus on clinical outcomes (Dang & Dearholt, 2018). The goal of this literature review is to identify and categorize good or high-quality Level I/II studies that evaluate the impact of exercise during concussion recovery. A systematic search was conducted in the PubMed database using MeSH terms {concussion} OR {mild traumatic brain injury} AND {exercise}, including publications from January 1, 2015 through early 2022. The search was focused on randomized clinical trials (RCTs) and systematic reviews with meta-analysis. After removal of titles that were not pertinent and publications focused on adults, four pediatric RCTs examining the impact of exercise on acute concussion recovery were identified (Dobney et al., 2018; Leddy et al., 2019; Leddy et al., 2021; Ledoux et al., 2022) as well as a relevant quasi-experimental study (Willer et al., 2019) and a large-scale prospective cohort study (Grool et al., 2018) of
good quality. In addition, two pediatric RCTs measured the impact of exercise in patients with persistent symptoms or prolonged recovery (Chan et al., 2018; Kurowski et al., 2017), and it is evident that there is a substantial volume of literature exploring the value of physical activity for patients with PPCS, with a rapidly growing interest in exercise as an intervention at all stages of recovery. The search also identified multiple systematic review papers with three level 1b reviews dedicated to adolescent RCTs, with a blended focus on both the acute and sub-acute/prolonged recovery phases (Languin et al., 2020; Powell et al., 2020; Shen et al., 2021). Table 1 outlines the research design, level of evidence, and stage of recovery for each study.

Table 1

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Research Design</th>
<th>Level of Evidence</th>
<th>Stage of recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dobney, 2018</td>
<td>Pilot RCT</td>
<td>Level 1B</td>
<td>Acute</td>
</tr>
<tr>
<td>Leddy, 2019</td>
<td>RCT</td>
<td>Level 1A</td>
<td>Acute</td>
</tr>
<tr>
<td>Leddy, 2021</td>
<td>RCT</td>
<td>Level 1A</td>
<td>Acute</td>
</tr>
<tr>
<td>Ledoux, 2022</td>
<td>RCT</td>
<td>Level 1A</td>
<td>Acute</td>
</tr>
<tr>
<td>Willer, 2019</td>
<td>Quasi-experimental</td>
<td>Level II A/B</td>
<td>Acute</td>
</tr>
<tr>
<td>Grool, 2018</td>
<td>Prospective cohort, large-scale, multi-center</td>
<td>Level II A/B</td>
<td>Acute</td>
</tr>
<tr>
<td>Chan, 2017</td>
<td>RCT</td>
<td>Level 1B</td>
<td>Prolonged</td>
</tr>
<tr>
<td>Kurowsky, 2017</td>
<td>RCT</td>
<td>Level 1B</td>
<td>Prolonged</td>
</tr>
<tr>
<td>Languin, 2020</td>
<td>Systematic review with meta-analysis</td>
<td>Level 1B</td>
<td>Acute</td>
</tr>
<tr>
<td>Powell, 2020</td>
<td>Systematic review with meta-analysis</td>
<td>Level 1B</td>
<td>Mixed</td>
</tr>
<tr>
<td>Shen, 2020</td>
<td>Systematic review with meta-analysis</td>
<td>Level 1B</td>
<td>Mixed</td>
</tr>
</tbody>
</table>

Note. Level and quality of evidence based on the Johns Hopkins Nursing Evidence-Based Practice Evidence Level and Quality Guide (Dang & Dearholt, 2018).
The following section follows Table 1 and summarizes each Level I and Level II study.

**Randomized Controlled Trials & Quasi-Experimental Research**

Dobney et al. (2018) performed a pilot randomized trial to evaluate the safety and feasibility of implementing early active rehabilitation (AR) at two weeks post-concussion compared with standard facility recommendations for exercise to begin at four weeks post-injury. AR consisted of aerobic activity as well as coordination drills, visualization, and education and was administered by a physical therapist and continued at home. Authors reported that symptoms decreased over time for all 20 participants and concluded that full clinical trials are safe and feasible, and will better determine the efficacy of AR in the acute recovery period (Dobney, 2018). In 2019, Leddy et al. published a landmark study of 103 adolescent athletes ages 13-18 presenting within 10 days of SRC who were randomly assigned to aerobic activity or placebo-like stretching. Individualized, sub-symptom threshold aerobic activity was prescribed based on treadmill testing done at the first visit, and both types of exercise were performed for approximately 20 minutes per day. Recovery was defined as being asymptomatic by a blinded physician assessment and having normal exercise tolerance with treadmill testing. After adjusting for age, sex, time from injury to first clinical visit, and concussion history, authors determined that the aerobic exercise group recovered significantly faster than the stretching group (P = 0.005), with a median of 17 days in the stretching group and 13 days in the aerobic exercise group. Leddy also reported that there was a decreased incidence of PPCS in the exercise group (4%) versus the stretching group (14%), although this did not reach statistical significance (P = 0.08).

Willer et al. (2019) built on this Leddy’s work by prescribing traditional rest to a similar group of adolescent athletes and comparing outcomes to Leddy’s matched samples. The median days to recovery for the rest group was significantly delayed (16 days) compared with the group prescribed aerobic activity (P = 0.02). In Willer’s quasi-experimental study, the incidence of PPCS was 13% which was similar
to Leddy’s stretching cohort (14%). No adverse events were noted in either study. Grool et al. (2018) performed a prospective, multicenter cohort study of more than 3000 patients ages 5 to 18 years comparing rest to all levels of physical activity, beginning within seven days of injury. Both unadjusted analysis and propensity score matching showed that early physical activity was associated with lower PPCS risk compared with no physical activity (24.6% versus 43.5% and 28.7% versus 40.1% respectively).

Leddy et al. (2021) went on to replicate his 2019 RCT with a multi-center study of 118 adolescents randomly assigned to aerobic exercise or a stretching group. The primary outcome measure was clinical concussion recovery within four weeks, defined by return to baseline symptoms, normal exercise tolerance, and a normal physical examination. Authors reported that patients assigned to the aerobic exercise group had a 48% decreased risk of PPCS compared to the control group (P=.039) with no adverse events reported. Leddy and colleagues recommended that providers should consider prescribing early sub-symptom threshold physical activity to children as treatment for SRC. The most recent RCT identified is called the Pediatric Concussion Assessment of Rest and Exertion (PedCARE) study and results were published in March 2022 in the British Journal of Sports Medicine (Ledoux et al., 2022). This multi-center RCT includes 456 children ages 10 to 17 years who were randomized into a traditional rest group (return to physical activity once symptom-free) or to a four-week physical activity protocol beginning at 72 hours post-injury. Authors report that among adherent participants, early physical activity was safe and associated with decreased symptoms at two weeks post-injury (Ledoux et al., 2022). In addition, two pilot RCTs examined the impact of active rehabilitation on PPCS in children ages 12 to 18 years with post-concussive symptom scores as the primary outcome measure (Kurowski et al., 2017; Chan et al., 2017). Both authors reported that exercise is safe, tolerable, and potentially beneficial for adolescents with PPCS, with greater rate of improvement or reduction in self-reported symptoms in the exercise groups compared with control groups.
**Systematic Reviews with Meta-Analyses**

Lastly, three systematic reviews examined the literature for pediatric RCTs for the last several decades and all reported encouraging results. Shen et al. (2021) identified five relevant RCTs and meta-analysis led to authors’ conclusion that aerobic exercise versus standard treatment significantly decreased symptom scores (P= .040) and time to recovery, but may not help with cognitive recovery. The stage of recovery of participants varied within the studies examined. Powell et al. (2020) also identified five pertinent RCTs published since 1965 and meta-analysis indicated that there is moderately significant evidence (level 1a) to support aerobic exercise in the acute phase of recovery as well as for persistent symptoms. Langevin et al. (2020) performed initial meta-analysis on seven RCTs and separated three RCTs focused on the acute phase of recovery, described as moderate quality evidence. Authors concluded that aerobic exercise has a positive impact on acute symptomatic recovery compared with control interventions for adolescents with SRC (Powel et al., 2020).

**Application to Practice**

Current research challenges the concept of rest and advocates for active rehabilitation to promote recovery and prevent PPCS in children with concussion. While there is solid evidence to support the benefit of exercise as treatment during acute concussion recovery, there is little understanding of the practical application in a pediatric clinic setting. Research protocols often include an exercise program and/or treadmill testing that are initiated during the concussion evaluation which may be challenging to mimic in a busy clinic practice. Systematic evaluation of a program that is following an evidence-based exercise protocol can help determine the impact on patient outcomes including whether treadmill testing may increase exercise participation at home and school. It can also provide valuable information about the practical challenges of implementation and sustainability within a pediatric specialty practice and the larger community. This project provides a formal evaluation of a
new initiative to evaluate the impact of active rehabilitation on concussion recovery in a well-established pediatric concussion clinic.

**Description of the New Initiative: Active Rehabilitation**

**Context, Setting, and Population**

The interdisciplinary Traumatic Brain Injury (TBI)/Concussion program at Dell Children’s Medical Center provides management of mild to moderate TBI including concussions, including children and adolescents. Evaluations are comprehensive and multimodal based on the 2018 CDC guideline for the management of mTBI in children (Lumba-Brown et al., 2018). This includes an assessment of risk factors for prolonged recovery, a validated symptom scale called the Post-Concussive Symptom Inventory (PCSI), neurological exam including balance testing, and neurocognitive assessment via ImPACT computerized testing. The plan of care is evidence-based with a focus on individualized education, symptom management, and active rehabilitation (Lumba-Brown et al., 2018; Gioia, 2015). Active rehabilitation encompasses return to academics with accommodations and rest breaks, as well as safe, non-contact physical activity, consistent with CDC guidelines (Lumba-Brown et al., 2018). The specialty clinic commonly sees children and adolescents at two weeks post-hospital or emergency department (ED) discharge, or several weeks/months following injuries managed by primary care physicians (PCPs), if not recovering as expected.

Clinic leadership planned and implemented a new initiative to assess and treat adolescent athletes in the first week following concussion, with a focus on sub-symptom threshold aerobic exercise as described in the literature. This includes treadmill testing in the clinic setting to guide safe exercise therapy and encourage consistent exercise participation at home and school. The target population is athletes 12 to 18 years of age, with mTBI consistent with concussion (negative or no head CT and initial Glasgow Coma Scale of 13-15). Mechanism of injury was not limited to sports-related concussion and
may include falls and other common mechanisms. It is anticipated that this intervention may improve symptom ratings, increase cognitive scores, and decrease time to recovery as well as the incidence of PPCS. Recruiting, triaging, and scheduling athletes age 12 and up in the early recovery period is integral to the initiative. Clinic leadership is hopeful that the new initiative will increase clinic volume and build rapport with community stakeholders such as school nurses, coaches, and ATs. The principal goal is to develop sustainable processes that lead to positive outcomes, patient satisfaction, and that meet the needs of the community. This quality improvement project will provide a formal program evaluation of this new initiative, including an analysis of the impact of active rehabilitation on sports concussion recovery. The Kellogg Model for Program Evaluation was used as a guide to develop and implement the project with a focus on linking resources to tangible outcomes.

**Theoretical Framework**

The W.K. Kellogg Foundation Model for Program Evaluation (W.K. Kellogg Foundation, 2017) was used to inform the strategic development of the initiative and to track the progress, performance, and impact of the program on its stakeholders. A theory of change and evaluative thinking was utilized to link program activities and outcomes, and how and why the desired change was expected to occur. A logic model was developed in collaboration with clinic leadership with a focus on tangible and intangible goals of the initiative. The logic model represents the theory of change and illustrates the links among resources, activities, outputs, and short, intermediate, and long-term outcomes of the new initiative that is being evaluated. See Figure 1.
### Logic Model – Active Rehabilitation following sports concussion

**Project:** New TBI/Concussion Clinic initiative – acute management of sports concussion  
**Goal:** Provide interdisciplinary evidence-based sports concussion management focusing on active rehabilitation to improve outcomes.

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>ACTIVITIES</th>
<th>OUTCOMES</th>
</tr>
</thead>
</table>
| **What we invest** | **What we do** | **Why This Project:**  
**Short-Term Results** | **Why This Project:**  
**Intermediate Results** | **Why This Project:**  
**Long-Term Results** |
| Clinic staff: NPs, AT, RN, MA, Neuropsychologist MD oversight | Comprehensive concussion evaluations within 3-5 days of injury:  
-Detailed history including risk factors  
-Symptom inventory  
-Balance & vestibular-ocular motor (VOM) testing  
-IMPACT cognitive testing  
-Treadmill testing  
-Evidence-based recs for active rehab  
-Academic accommodations  
-Symptom management including exercise therapy | Student athletes, parents |  
3+ evals/week achieved  
Increased knowledge of concussion recovery  
Motivation to participate in active rehab  
Participation in exercise therapy 3x/week  
Participation in academics with accommodations  
Decreased anxiety and stress r/t restrictions  
Positive attitude towards recovery |  
Decrease in school absences  
Decreased psychotherapy referrals  
Decreased incidence of prolonged recovery  
Decreased risk for re-injury from deconditioning or premature return to play |
| Leadership endorsement: Directors of Neurosciences, Clinic Director, Clinic Manager | Weekly re-evals:  
-Symptom Inventory  
-Balance/VOM testing | 6-12 re-evals/week |  
6+ evals/week achieved  
Decreased symptom scores  
Normal balance/VOM testing | |
| Endorsement & referrals from Community ATs: Local school district, LoneStar Soccer | Dedicated clinic space, time | |
| Commercial grade treadmill | |

**Why This Project:**

- **Short-Term Results:**
  - 6+ evals/week achieved
  - Decreased symptom scores
  - Normal balance/VOM testing

- **Intermediate Results:**
  - 3+ evals/week achieved
  - Increased knowledge of concussion recovery
  - Motivation to participate in active rehab
  - Participation in exercise therapy 3x/week
  - Participation in academics with accommodations
  - Decreased anxiety and stress r/t restrictions
  - Positive attitude towards recovery

- **Long-Term Results:**
  - Decrease in school absences
  - Decreased psychotherapy referrals
  - Decreased incidence of prolonged recovery
  - Decreased risk for re-injury from deconditioning or premature return to play
### PEDIATRIC CONCUSSION AND ACTIVE REHAB

**HR monitors**
- IMPACT cognitive testing
- Treadmill testing
- Evidence-based recs for active rehab
- Recs for clearance with evidence of full recovery

**Impact tests & staff certification**
- Community collaboration
  - Community coaches, ATs, nurses
  - Needs assessment surveys and open communication with ATs & school nurses

**Evidence-based recs for active rehab**
- Improved cognitive scores
- Tolerance of full academic schedule
- Improved exercise tolerance & physical exertion without symptoms

**Recs for clearance with evidence of full recovery**
- Improved patient/parent satisfaction

**Assumptions:**
- Parents, coaches, ATs, and athletes want (athletes) to return to play as soon as possible following concussion.
- Parents, coaches, ATs, and athletes want to prevent re-injury and poor outcomes following concussion.
- Athletes prefer active rehabilitation.
- Sub-symptom threshold exercise in the acute recovery period is safe.
- Active rehab with exercise therapy will improve symptom scores and speed recovery.

**External Factors:**
- Covid restrictions may continue and limit sports participation/referrals
- Referrals may exceed or fall short of expectations
- Core staff (NP, AT, RN, MA) turnover may limit clinic capacity
- Program funding and support may change within Pediatric Neurosciences

**Community collaboration**
- Improved cognitive scores
- Tolerance of full academic schedule
- Improved exercise tolerance & physical exertion without symptoms

**Expansion of referral base**
- Programmatic growth to 900 sports concussion visits/year
- Increased community understanding of concussion recovery
- School district support of active rehab

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The Logic Model allows for both formative and summative questions to be developed. Formative questions are focused on program activities, outputs, and short-term outcomes (W.F. Kellogg Foundation, 2017). Formative questions are targeted to improve care and include:

1. Is the clinic receiving and accommodating three to four new athlete referrals per week, and scheduling evaluations in a timely manner?
2. Are comprehensive evaluations including treadmill testing feasible for the clinic team?
3. What are the barriers to exercise therapy in the community (home/school/practice)?
4. Are athletes and parents satisfied with the active rehabilitation model of care?

Summative questions can be used to demonstrate results and effectiveness of the new initiative as well as the intermediate-term outcomes and impact on stakeholders and the community (W.F. Kellogg Foundation, 2017). Summative questions are intended to support or prove the value of the program.

1. Does treadmill testing in the clinic increase the rate of exercise participation outside the clinic?
2. Is exercise therapy associated with decreased symptoms, decreased time to recovery, and decreased incidence of PPCS in this setting?
3. Is the clinic team providing multimodal care that follows the CDC guideline for management of mTBI in children (Lumba-Brown et al., 2018)?
4. Is this model of care meeting the needs of community stakeholders and is it sustainable?

**Evaluation Type, Methodology, and Approach**

This evaluation includes a mixture of the three major types of evaluation. A formative or implementation evaluation was conducted to monitor processes and better understand if the initiative is being instituted as planned. The formative evaluation will seek to identify strengths and weaknesses of the effort, and to evaluate if processes are meeting the needs of the community. Performance monitoring of pre-established clinic goals will provide early warning signs of problems that stakeholders can act upon as well as objective data that highlights the merits of the program. An outcome or
summative evaluation will provide data analysis to measure the impact of the evidence-based initiative on sports concussion recovery. A case study methodology will be followed to better understand the initiative in its context, using a combination of qualitative and quantitative data. This will provide an in-depth analysis of the specific program and its ability to meet the needs of stakeholders and the surrounding school districts.

A developmental evaluation approach will be used to support the process of innovation within the neurosciences program at this children’s hospital. The TBI/Concussion clinic is growing and the new initiative is in a state of continuous development and adaptation. The health care environment is often changing and potentially unpredictable in the setting of the pandemic. The evaluation will emphasize learning to refine the innovation and to respond to the environment, with the ultimate goal of empowering the team with the tools and knowledge to support quality improvement and sustainability of the clinic within the community.

In addition, a developmental approach is helpful in evaluating a program that is focused on adolescents. Adolescents are viewed as participants in their care and primary stakeholders in the program along with their parents. The developmental phase of adolescence is a time of rapid change in the body and brain including ongoing mental and emotional growth and the evolution of identity, independence, self-control, and self-confidence (Konrad et al., 2013). These factors impact the care of this population and will be honored within the developmental evaluation approach. The logic model, formative and summative questions, and approach framed the development of this project’s aims and objectives and associated measures.

**Aims and Objectives**

There are three overarching aims of the comprehensive program evaluation. See Appendix A for an outline of aims and objectives.
Aim 1: Perform an implementation evaluation of the initiative with a focus on the sustainability and impact of the program within the community. Aim 1 provides stakeholders with a summary of successes and challenges of clinic processes and collaboration with school nurses and ATs. This will include an assessment of the team’s ability to secure athlete referrals as well as the timeliness of the referral process, with a goal of initial clinic visits within one week of injury. Evaluation of athletes in the acute recovery period is essential to ensure interventions are initiated in a timely manner. Community questionnaires will provide qualitative and quantitative data to evaluate the ability of the program to meet stakeholder needs and the feasibility of implementing aerobic exercise outside the clinic.

Aim 2: Provide performance monitoring of the care provided by the interdisciplinary team using quantitative and qualitative data. Aim 2 allows for quality improvement measures to occur in real time. This will include the development of parent satisfaction tools and processes to inform the team and allow for QI measures to occur in real-time. Performance monitoring will also include the implementation of a process to track adherence to pre-established clinic goals that are aligned with CDC guidelines for multimodal assessment of mTBI. This information will provide stakeholders with performance data to distinguish the program from other providers.

Aim 3: Evaluate the impact of active rehabilitation on outcomes in sports concussion recovery. Aim 3 provides a summary of findings related to patient outcomes, cost-benefit analysis, and the identification of vulnerable populations. This outcome evaluation will describe the impact of treadmill testing on athlete participation in exercise therapy based on self-reports of exercise outside the clinic. It will include data analysis of the impact of exercise on standardized symptom ratings, cognitive scores, and time to full recovery with a comparison of outcomes for patients that do not participate in treadmill testing and/or exercise therapy. The incidence of persistent post-concussive symptoms (PPCS) in
athletes who used the treadmill and/or exercised will be compared to those who did not and to the benchmark for concussion recovery in children. A cost-benefit analysis of predicted and any actual decrease in PPCS will illustrate the tangible benefit of active rehabilitation in this population. Lastly, a comparison of outcomes for at-risk populations such as families with low socioeconomic status and Hispanic ethnicity will be provided.

The final report will be comprehensive to include program successes, challenges, and recommendations for further program development and improvement, based up on the findings. A final presentation and a formal report will be provided to all stakeholders. Appendix A outlines the three overarching aims and 4-5 specific objectives for each aim.

Cost-Benefit Analysis

Prior to implementation, a comprehensive cost-benefit analysis of the new initiative was performed. Tangible and intangible benefits were largely focused on the outcome of decreasing PPCS, because PPCS leads to difficulties in physical, emotional, social, and school functioning which impact health-related quality of life (Rozbacher et al., 2016; Novak et al., 2016). Corwin et al. (2020) presents the first objective data on the direct costs of post-concussive syndrome in children and concludes that the cost per patient for medical and educational needs (homebound tutoring) averages $3557 with a 95% confidence interval range of $2886 to $4257. Because programmatic data for the cost of PPCS and/or post-concussive syndrome per patient is not available, this data will be used to calculate the financial benefit to society based on an anticipated 5% decrease in PPCS with the new initiative.

The tangible benefits of decreasing PPCS also include decreased school absences and decreased referrals for psychotherapy. An important component of PPCS management is to address psychological factors and provide psychoeducation and coping strategies through focused cognitive behavioral intervention (McNally et al., 2017). The clinic practice routinely refers patients for focused
psychotherapy if mTBI symptoms persist beyond four weeks, so a decrease in referrals will mimic a
decrease in incidence of PPCS. Children who develop PPCS are reported to have a higher number of
school absences compared to those who recover from concussion as expected. Babcock et al. (2013)
reported a mean of 7.4 days missed by children with PPCS and this data will be used to calculate the
benefit to the school district. According to the Texas Education Agency (2020), school districts receive
state funding based on Average Daily Attendance (ADA), and administrators strive to improve
attendance rates in part because the school loses money when a child is absent (My Texas Public School,
2021). The total annual budget for our local school district ($1.6 billion) was divided by the total number
of students (78,000) to obtain a dollar amount per student ($20,512) (Austin Independent School
District, 2020). This was divided by the number of school days (180) to monetize the value of one missed
day ($114).

A cost of care objective for this program evaluation is to measure the incidence of PPCS in
adolescents who performed treadmill testing and participated in exercise therapy at least two times per
week at home or school. Using time to recovery (> 28 days) from the clinic database, the incidence of
PPCS will be calculated and compared to the rate in patients who did not perform treadmill testing
and/or participate in exercise therapy outside the clinic. It can also be compared to the national
benchmark data of 20-30% rate of PPCS. A predicted 5% decrease in PPCS is used to quantify the
associated impact of decreased missed school days and decrease in referrals for psychotherapy.
Resources are monetized based on four new patient visits per week (16 per month) multiplied by the
predicted 5% decrease in PPCS. See Table 2.
Table 2

Categorized Costs and Benefits

<table>
<thead>
<tr>
<th>Category</th>
<th>Perspective</th>
<th>Cost</th>
<th>Monetized benefit</th>
<th>Intangible benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreased need for referrals for psychotherapy for brief intervention (CBT) x 4 sessions</td>
<td>Patient Insurance Co</td>
<td>Decreased referrals by 5% = 0.8 pts/mo x 4 sessions each (60 min) at billable rate CPT 90837 $141 a = $451</td>
<td></td>
<td>Improved mental health and quality of life</td>
</tr>
<tr>
<td>Decrease in school absences</td>
<td>Student School district Tax payers/ Community</td>
<td>Decreased PPCS by 5% = 0.8 pts/month x 7.4 days missed = 5.9 days/mo x $114/day = $673</td>
<td></td>
<td>Increased academic participation &amp; learning</td>
</tr>
<tr>
<td>Decreased healthcare costs</td>
<td>Patient</td>
<td>Decreased PPCS by 5% = 0.8 pts/month x $3557 (cost per pt) = $2846</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Implementation of the Program Evaluation

Process Evaluation

Data Collection

A needs assessment questionnaire was sent to athletic trainers (ATs) with the local school districts and with a private soccer organization that is affiliated with the children’s hospital and clinic. The 5-point Likert tool was developed specific to AT scope of practice following review of the National Athletic Trainers’ Association (NATA) position statement on management of sport concussion (Broglio et al., 2014). The tool includes three statements that assess the level of knowledge ATs have about concussion recognition, and their comfort level in talking with parents about active rehabilitation during concussion recovery. The tool also evaluates whether ATs have adequate information and referral
resources to give to parents for medical evaluation following concussion, and if they would like direct communication with the clinic AT throughout the recovery period.

Lastly, the questionnaire assesses the ATs perspective of barriers to implementing aerobic exercise in the acute recovery phase, with an opportunity for free text responses. This information is used to better understand AT knowledge and perspectives as well as challenges with implementation of aerobic exercise that may be addressed. Potential barriers include AT knowledge deficit of the safety and benefit of aerobic exercise in the recovery period and/or a strict interpretation of University Interscholastic League (UIL) return to play guidelines. The UIL is the governing body for public high school sports in Texas and ATs are expected to monitor athletes through four steps of increasing physical activity prior to contact game play. This process begins once the athlete has been cleared by a medical provider, with the assumption that the athlete is symptom-free.

A similar questionnaire was developed and sent to local school nurses to assess their understanding of concussion recovery, the benefits of active rehabilitation for both return to learn and return to play, and nurses’ knowledge of the referral process for the TBI/Concussion Clinic. The foundation for this tool is the CDC heads up website which offers concussion information specific to the school nurse role (Centers for Disease Control and Prevention, 2021b).

Both the AT and nurse tools include an open-ended question to identify preferred topics and venues for concussion education that clinic staff can provide in the future. All questionnaires were created via REDCap and emailed through distribution lists created for ATs and school nurses for Austin and surrounding school districts. Lastly, data collection includes the referral source for each patient as well as the date of the first clinic visit, both of which are entered into the REDCap clinic database, which is further described in the outcome evaluation. This data was used to evaluate the ability of the clinic to secure timely referrals and to schedule athletes for an initial visit within one week of injury, to allow for
timely implementation of active rehabilitation. In addition, staff interviews were conducted to better understand the scheduling and triage processes.

**Data Analysis Plan**

Data from the needs-assessment tools was compiled in a REDCap report and downloaded in STATA Version 17 (StataCorp, College Station, Texas) where the frequency of each response and mean score for each question was calculated. Qualitative data analysis included appropriate categorization of free text comments regarding educational needs and barriers to community exercise therapy. A REDCap report provided the number of community referrals from ATs and school nurses, and through STATA, the range and mean number of days to the first clinic visit was calculated. This descriptive data analysis provides the clinic team with objective information to guide QI initiatives for community education, decreasing barriers to exercise therapy in the community, and increasing referrals. This information allows for an exploration of nurse triage and scheduling processes with a goal of decreasing time to the first clinic visit.

**Performance Monitoring**

**Data Collection**

Parent satisfaction tools were developed and used to collect quantitative and qualitative data for performance monitoring. A process was developed for short questionnaires to be automatically emailed to the parent when final visit information is entered into the REDCap database at the time of clinic discharge. The brief tool consists of four questions with a 5-point Likert scale (Strongly disagree 1, Disagree 2, Neutral 3, Agree 4, Strongly Agree 5). The questionnaire assesses the level of satisfaction with the education provided on concussion recovery and exercise therapy. It also asks if the parent feels the team helped the athlete to safely return to school and to physical activity, and to recover from the injury. A second tool was developed to evaluate parent satisfaction for all other clinic patients (non-athletes). This tool is quite similar which allows for group comparisons, but it excludes verbiage specific
to exercise therapy. Both tools include an open-ended question to allow for comments or suggestions to improve the program. To optimize response rates, parents are notified at the time of clinic discharge that they will receive a questionnaire via email, and asked to please take a moment to provide honest feedback to the clinic team.

Performance monitoring also includes an assessment of adherence to CDC guidelines for multimodal assessment based on the completion (or not) of four components of comprehensive concussion evaluation. The first component is screening for known risk factors for prolonged recovery, including pre-existing attention or learning difficulties, anxiety or depression, prior concussions, and pre-injury migraines or headaches (McNally et al., 2013, Peterson et al., 2015). This information is routinely entered into the clinic database if it was collected during the visit as intended. Similarly, standard data collection includes Post-Concussive Symptom Inventory (PCSI) ratings and ImPACT computerized cognitive scores for any patient that completed these assessments. The last component is computerized balance testing as part of a comprehensive neurological exam to assess concussion recovery. A manual chart review was required to identify whether or not balance testing was performed. The chart review includes a percentage of total athletes seen from August 1, 2021 through the end of the evaluation period.

**Data Analysis Plan**

Descriptive data analysis was used to provide meaningful performance monitoring to clinic staff and leadership. Similar to process evaluation procedures, parent satisfaction data was compiled in a REDCap report and downloaded in STATA where the frequency of responses and mean score for each question were calculated. The clinic goal is for 80% satisfaction or higher (overall ratings of 4 out of 5) and mean scores from parents of athletes 12 or older can be compared to non-athletes using a T-test. Other group comparisons may include athletes who participated in treadmill testing and those who did
not. This data is targeted to tease out positive or negative feedback specific to the new initiative, explore parent perceptions of the impact of exercise therapy, and guide the clinic team towards improvement measures specific to this population. Qualitative data from free text comments was summarized into categories of strengths and weaknesses to allow for targeted QI measures.

Data for the first three components of multimodal assessment was reviewed via REDCap reports, including risk factors for prolonged recovery, self-rated symptom scores, and cognitive testing percentile scores. The rate of compliance for these performance measures was calculated with the assumption that the information is present in the database for any patient that received that assessment. Rate of compliance with balance testing was manually calculated as a percentage based on the number of charts that have documentation of balance testing out of the total number of charts reviewed. These performance measures were used to prove that the clinic is adhering to its foundational mission to provide high-quality evidence-based concussion care. Exemplary performance data may be used to distinguish this program from other concussion providers and highlight it as a center of excellence.

Outcome Evaluation

Data Collection

The TBI/Concussion Clinic maintains a REDCap database with an extensive collection of variables for each patient visit. This includes patient demographics, date of injury and injury characteristics, risk factors for prolonged recovery, symptom ratings, cognitive scores, referrals for psychotherapy, and date of functional recovery. Functional recovery is defined by return to baseline symptom scores, normal physical examination, and ImPACT computerized cognitive scores at actual or predicted baseline. This data is utilized to evaluate and improve quality measures in the clinic. An institutional Internal Review Board exempt determination was received prior to the initiation of data collection in 2017 and renewed in 2020. In planning for the program evaluation, database variables were added including referral
source, symptoms > 28 days (yes/no), athlete 12 or older (yes/no), treadmill testing (yes/no), treadmill testing within two weeks of injury (yes/no), and self-reported participation in aerobic exercise at least two times per week at home or school (yes/no). This quantitative database information was used to measure the impact of treadmill testing and participation in aerobic exercise on concussion recovery including symptom ratings and ImPACT cognitive scores. It was also used to evaluate the impact of exercise on time to functional recovery and the incidence of PPCS. Disaggregated data on socioeconomic status (via insurance) and race and ethnicity are standardly collected in the clinic database. This information was used to evaluate outcomes specific to vulnerable populations who are at risk for diminished quality of life following mTBI.

**Data Analysis Plan**

The outcome evaluation involves multiple analyses of categorical relationships that revolve around the use of the treadmill (or not). Bivariate correlations were used to assess the impact of a predictor (treadmill yes/no) on the outcome of whether or not the athlete participated in exercise outside the clinic. Chi-square analysis was used to explore this one to one relationship with no confounding variables. The relationship of treadmill use (and/or exercise participation) and the development of PPCS is also categorical in nature. Multivariate logistic regression could potentially be used to evaluate this relationship, with the consideration of confounding variables such as risk factors for prolonged recovery. However, the small numbers within subgroups did not provide sufficient power to consider confounding variables. For this reason, Chi-square analysis of the relationship was performed, using the more rigorous Fisher’s exact analysis when any subgroup number was less than five. A calculation and description of the incidence of PPCS in the total population of athletes and in at-risk groups is also provided.
A similar model was used to analyze the impact of treadmill use (and/or exercise participation) on both symptom ratings and cognitive scores. The first visit cognitive scores and symptom ratings were used as a baseline to evaluate for improvement at each subsequent clinic visit. From the continuum of scores and ratings, we calculated the mean change between visit one and future visits. An analysis of the normality of variable differences was used to determine the skewness of data, with a skewness target of -1 to 1. When the data was skewed (outside this range), a non-parametric, Wilcoxon rank sum test was used to investigate the relationship between the exposure (treadmill use or exercise participation) and the outcome. In sets of data where there was minimal skewing, a student T-test was used to evaluate the difference in mean scores as related to the predictor (treadmill use or exercise participation). Similarly, the impact of the predictor on the time to recovery was analyzed through the calculation of mean days to recovery, followed by a non-parametric or student T-test. See Appendix B for a table outlining the data management plan.

The total number of athletes who performed treadmill testing is an integral part of this data collection and analysis. It was calculated as a percentage of the total number of athletes seen during the evaluation period beginning in September 2021. This data is the foundation for exploration of barriers to treadmill use and helps answer the question of whether or not treadmill testing is feasible in this clinic setting. Over time, these outcomes may be re-evaluated as referral processes are improved and the referral base grows. As more athletes are referred and scheduled in a timely manner, this will allow for the initial evaluation and interventions to consistently occur in the acute recovery period which is integral to improving outcomes. If barriers to treadmill use in clinic can be addressed to allow for consistent use, the increased numbers may lead to more valuable and meaningful information.

Timeline

The new initiative was launched in the fall of 2021 following final preparations including treadmill setup in the clinic and staff training on the treadmill protocol. Evaluation planning began right
away and new database variables were added to the existing clinic database. Planning meetings were held with clinic leadership and staff was updated via monthly staff meetings throughout the fall and winter. In February 2022, data collection began with the development and distribution of parent satisfaction tools. As questionnaires were received through the spring, data was reviewed and shared with the team in real-time. AT and nurse assessment tools were distributed in April and early May, and data compilation and analysis will occur through early June. Clinic protocols include data collection and entry of all variables into the REDCap database at the time of each patient discharge. REDCap database review and data cleaning began in March, and ongoing review including manual chart reviews will continue until performance and outcome data is analyzed in late June. The evaluation was written and finalized in June and July, and presented to clinic stakeholders in early August. See Figure 2.

**Figure 2**

*Implementation Timeline*

![Implementation Timeline](image)

**Reliability of Data Collection**

Data is collected during each visit and entered into the REDCap database by the provider seeing the patient. There are only two providers seeing patients and entering data, and both were trained to follow a systematic procedure for data collection and entry. Paper forms listing each variable are used to collect data in real time during or immediately following each visit. The majority of variables are
converted into nominal data on the paper form to allow for rapid entry with decreased risk of error. There are several REDCap field types that are open text or unrestricted fields and these were narrowed with parameters to decrease potential errors wherever possible. Data verification involves a second review for 10% of all visits and the verified rate of error has been consistently less than 10 percent in the past. If the rate of error is found to be greater than 10% at any point in time, the evaluation plan is to revert to 100% second review for data verification. Much of the data is objective including patient symptom scores, and cognitive scores. However, variables such as functional recovery require provider interpretation of return to baseline and/or symptoms that may be related to non-injury factors. Providers follow an agreed upon definition of functional recovery and interpretation of other potentially subjective variables to optimize the reliability of data. In terms of community assessment tools, participants are instructed that this information is anonymous which encourages honest feedback. Parent questionnaires are sent following clinic discharge which helps to ensure that participants are comfortable providing positive and negative ratings and comments. The blinded categorization of free text responses will allow for objective interpretation of qualitative data.

Validity of Data Collection

Standard 5-point Likert parent satisfaction questionnaires were developed with a goal of obtaining non-biased, objective data. The face-validity of the tool was assessed via review by TBI/Concussion Clinic leadership including a PhD-prepared neuropsychologist. Athlete and non-athlete tools are very similar so that the data can be compared and contrasted fairly. The community AT assessment tool was reviewed by an AT director and was first piloted first with a small group within the private soccer organization. Feedback was reviewed and appropriate revisions were made prior to full distribution to school districts to ensure that the information gathered was useful and addressed all objectives. Three additional questions were added to further explore AT knowledge of active rehabilitation and barriers to exercise therapy in the school. Similarly, the school nurse questionnaires
were reviewed by the school district nurse director and revised slightly to clarify potentially confusing
verbiage prior to distribution.

Prior to data analysis, the information from the clinic database was manually “cleaned” to
further ensure reliability and validity. This involved a review for missing data followed by a manual chart
review to accurately provide the information. Data cleaning was targeted to identify inconsistencies in
data relationships such as an eight-year-old patient being identified as an athlete (defined as 12 or
older). It was also designed to double-check duplicative data points, such as the date of functional
recovery being aligned with a positive data point of PPCS (defined by symptoms greater than 28 days).
Lastly, data cleaning allowed for the identification of impossible data points that fall outside the range of
available data, such as a date that had not occurred yet or a cognitive score outside the potential range.

A variety of data collection procedures and analyses have been described, which allows for a
comprehensive program evaluation that includes implementation processes, performance monitoring,
and an outcome evaluation (W. F. Kellogg, 2017). Quantitative and qualitative data were compiled to
ensure the descriptive data analysis is meaningful to the clinic team. The goal is to provide data that
highlights program strengths and leads to targeted, real-time QI measures to improve clinic processes,
collaboration, and sustainability within the community. In addition, the application of inferential
statistical methods to provide an objective measurement of the impact of active rehabilitation on
concussion outcomes.

Findings

Implementation Evaluation

Referrals & Clinic Processes

The first aim is to evaluate the effectiveness of clinic processes & collaboration with the
community. This includes the ability of the clinic to secure new referrals from community ATs and
nurses and to schedule athletes within one week of injury. Timely referrals are required for athletes to be scheduled and evaluated in the acute recovery period. The date the referral was received is not collected in the database, and the information can be challenging to locate in the EHR. Since the implementation of the new initiative in September 2021, the clinic has evaluated 105 adolescent athletes age 12 and up with concussion. Of the total referrals, 65 (62%) were documented as sports-related concussions with blunt head trauma (12%), falls (10%), and motor-vehicle crash (8%) cited as the next most common mechanisms. Athletes were managed similarly with this initiative, regardless of mechanism of injury, as long as there were no contraindications due to concomitant injuries. The number of days from injury to the first visit ranges from 2 to 117 days, with a mean of 20.58 days. Because this data is heavily skewed, the median (14) with interquartile percentages was calculated and displayed in a box plot in Table 3.

Figure 3

Days from injury to first visit

Of the 105 athletes seen, there were only five referrals (5%) from community coaches, ATs, and school nurses. Table 4 illustrates the number of days from injury to the first clinic visit for these referrals.
Table 3

Referrals from community ATs/Nurses

<table>
<thead>
<tr>
<th>Athlete</th>
<th>Days from injury to visit 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
</tr>
</tbody>
</table>

The date of referral is not tracked, but we do know that three out of the five referrals from community ATs and school nurses were timely enough to allow for the first visit to occur within the benchmark of one week of injury. Referrals are commonly received from the clinic’s long-standing sources such as the Emergency Department (ED) and Primary Care Physicians (PCPs), and the majority of the remaining 100 patients were referred from these sources, 37% and 42% respectively. Of the 105 athletes, 24 (23%) were scheduled within the target of one week, and 53 (50%) total were scheduled within two weeks, which is generally considered the acute recovery period. Of the 105 total athletes seen, 17 (16%) were seen after 30 days from injury.

Since there were so few referrals from the new referral base (community ATs and nurses), further analysis was completed to better understand the timeline and referral processes from long-standing referral sources, the ED and community PCPs. The ED referral process was recently streamlined and now involves direct communication between the ED case manager to the Neurosciences Department via a spreadsheet with all patients referred to a Neurosciences clinic. The TBI/Concussion clinic staff reviews the spreadsheet regularly and calls families to schedule. The days from injury to first visit for the total 39 ED referrals was minimally skewed compared to the overall data, with a range of 4 to 43 days, a mean of 12.69 and a median of 10 days. One-third of the referrals were seen for the first
evaluation within one week of injury and 74% were seen within two weeks of injury. Clinic staff reported that patients seen in the ED with concussion are sometimes not listed on the ED referral spreadsheet. Clinic staff becomes aware of this when the parent of a patient seen in the ED (not on the spreadsheet) eventually calls the clinic to schedule an evaluation (M. O’Connor, personal communication, June 22, 2022).

Of the 45 referrals from PCPs, the data is skewed, mimicking the overall data. The range of days from injury to first visit is from 3 to 117 with a median of 21. There were only three athletes seen within one week of injury and 14 seen within two weeks of injury. This is not surprising since PCPs commonly refer patients with complicated concussions who are not recovering as expected, often more than four weeks post-injury. However, clinic staff reported that PCP referrals are often delayed within the Neurosciences electronic health record (EHR) (M. O’Connor, personal communication, May, 2022). An exploration of how referrals are received into the EHR was conducted, and demonstrated that PCP referrals are generally received via fax to the comprehensive neurology “bucket” in the EHR. Referrals for concussion may sit in this location until a neurology nurse has time to triage the referral and move it into the TBI/Concussion clinic “bucket” for review and scheduling by clinic staff (S. Barker, personal communication, June 27, 2022). Due to neurology staff and provider shortages, the neurology “bucket” in the EHR may have several hundred referrals for review, leading to potential delays in triage and scheduling of PCP referrals.

Without the date of referral for each athlete, it is unclear how much clinic processes may have impacted the time between injury and the first visit. Staff interviews were conducted to get a sense of the ability to schedule athletes as soon as possible once the referral is received. The clinic nurse reported that she had been consistently able to schedule athletes in a timely manner through the winter and spring, however it was not always possible during the fall football season, when the volume of referrals was higher (M. Montez, personal communication, March, 2022).
Community Collaboration

There were 132 AT questionnaires distributed and 54 responses (41%) were returned, and 124 nurse questionnaires distributed with 73 responses (58%) received. The initial AT tool was piloted with trainers from a private soccer organization (n = 12 surveys returned) and after review of results, three more questions were added for distribution to the larger public-school AT group (n = 42 surveys returned). Four survey statements specifically addressed referral resources and communication with the TBI/Concussion clinic. Tables 4-7 illustrate the frequency of Likert scale responses and mean scores.

Table 4

*I have the referral info and resources I need to give to parents and/or students for medical eval following concussion.*

<table>
<thead>
<tr>
<th>AT Response</th>
<th>Frequency</th>
<th>Percent</th>
<th>Nurse Response</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree (5)</td>
<td>23</td>
<td>42.60%</td>
<td>Strongly Agree</td>
<td>8</td>
<td>10.96%</td>
</tr>
<tr>
<td>Agree (4)</td>
<td>20</td>
<td>37.04%</td>
<td>Agree</td>
<td>15</td>
<td>20.55%</td>
</tr>
<tr>
<td>Neutral (3)</td>
<td>7</td>
<td>12.96%</td>
<td>Neutral</td>
<td>23</td>
<td>31.51%</td>
</tr>
<tr>
<td>Disagree (2)</td>
<td>3</td>
<td>5.55%</td>
<td>Disagree</td>
<td>21</td>
<td>28.77%</td>
</tr>
<tr>
<td>Strongly Disagree (1)</td>
<td>1</td>
<td>1.85%</td>
<td>Strongly Disagree</td>
<td>6</td>
<td>8.22%</td>
</tr>
<tr>
<td>Total Responses</td>
<td>54</td>
<td>100%</td>
<td>Total Responses</td>
<td>73</td>
<td>100%</td>
</tr>
<tr>
<td>Mean Score (1-5)</td>
<td>4.13</td>
<td></td>
<td>Mean Score (1-5)</td>
<td>3.05</td>
<td></td>
</tr>
</tbody>
</table>

Table 5

*It would be helpful to have more information about the TBI/Concussion clinic at Dell Children’s.*

<table>
<thead>
<tr>
<th>AT Response</th>
<th>Frequency</th>
<th>Percent</th>
<th>Nurse Response</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree (5)</td>
<td>18</td>
<td>42.86%</td>
<td>Strongly Agree</td>
<td>40</td>
<td>55.56%</td>
</tr>
<tr>
<td>Agree (4)</td>
<td>17</td>
<td>40.48%</td>
<td>Agree</td>
<td>28</td>
<td>38.89%</td>
</tr>
<tr>
<td>Neutral (3)</td>
<td>7</td>
<td>16.67%</td>
<td>Neutral</td>
<td>2</td>
<td>2.78%</td>
</tr>
<tr>
<td>Disagree (2)</td>
<td>0</td>
<td>0%</td>
<td>Disagree</td>
<td>2</td>
<td>2.78%</td>
</tr>
<tr>
<td>Strongly Disagree (1)</td>
<td>0</td>
<td>0%</td>
<td>Strongly Disagree</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>
Table 6

It would be helpful to communicate directly with the TBI/Concussion clinic AT/RN if I have an athlete that needs a medical eval.

<table>
<thead>
<tr>
<th>AT Response</th>
<th>Frequency</th>
<th>Percent</th>
<th>Nurse Response</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>23</td>
<td>54.76%</td>
<td>Strongly Agree</td>
<td>35</td>
<td>47.95%</td>
</tr>
<tr>
<td>Agree</td>
<td>15</td>
<td>35.71%</td>
<td>Agree</td>
<td>34</td>
<td>46.58%</td>
</tr>
<tr>
<td>Neutral</td>
<td>4</td>
<td>9.52%</td>
<td>Neutral</td>
<td>4</td>
<td>5.48%</td>
</tr>
<tr>
<td>Disagree</td>
<td>0</td>
<td>0%</td>
<td>Disagree</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>0</td>
<td>0%</td>
<td>Strongly Disagree</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Total responses</td>
<td>42</td>
<td>100%</td>
<td>Total Responses</td>
<td>73</td>
<td>100%</td>
</tr>
<tr>
<td>Mean score</td>
<td>4.45</td>
<td>100%</td>
<td>Mean Score (1-5)</td>
<td>4.42</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 7

It would be helpful to receive direct communication from the TBI/Concussion clinic team following medical evaluation, including the recommendations and plan of care for my student/athlete.

<table>
<thead>
<tr>
<th>AT Response</th>
<th>Frequency</th>
<th>Percent</th>
<th>Nurse Response</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>25</td>
<td>59.52%</td>
<td>Strongly Agree</td>
<td>51</td>
<td>69.86%</td>
</tr>
<tr>
<td>Agree</td>
<td>14</td>
<td>33.33%</td>
<td>Agree</td>
<td>20</td>
<td>27.40%</td>
</tr>
<tr>
<td>Neutral</td>
<td>3</td>
<td>7.14%</td>
<td>Neutral</td>
<td>2</td>
<td>2.74%</td>
</tr>
<tr>
<td>Disagree</td>
<td>0</td>
<td>0%</td>
<td>Disagree</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>0</td>
<td>0%</td>
<td>Strongly Disagree</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Total Responses</td>
<td>42</td>
<td>100%</td>
<td>Total Responses</td>
<td>73</td>
<td>100%</td>
</tr>
<tr>
<td>Mean Score (1-5)</td>
<td>4.52</td>
<td>100%</td>
<td>Mean Score (1-5)</td>
<td>4.67</td>
<td>100%</td>
</tr>
</tbody>
</table>

Results indicate that the majority of ATs (80%) feel they do have the referral resources and information needed to give to parents for medical evaluation following concussion, while only 31.5% of
nurses feel the same. The overwhelming majority of ATs (83%) and nurses (93%) would like more information about the TBI/Concussion clinic. Desire for direct communication with the TBI/Concussion team was strong both in terms of the referral for medical evaluation (90% and 95% of ATs and nurses agree, respectively), and for communication of recommendations following the evaluation (93% and 97% of ATs and nurses agree, respectively).

**Treadmill Testing**

Another objective of the implementation evaluation is to explore the team’s ability to provide treadmill testing in the clinic and evaluate barriers to aerobic exercise in the community. Of the 105 athletes seen, a total of 26 (24.8%) performed treadmill testing in the clinic. Staff interviews were conducted to explore barriers to performing treadmill testing. Challenges reported include staff hesitation/lack of comfort with treadmill procedure, insufficient time, athlete symptom burden and/or athlete reluctance, and lack of appropriate footwear (K. Euwer, personal communication, April, 2022). Of the 105 athletes seen, a total of 80 (76.9%) endorsed aerobic activity at home or school at least two times per week during the acute recovery period. Tables 8 and 9 summarize the two questions on the AT tool that addressed potential barriers to supervising aerobic exercise at school during concussion recovery.

**Table 8**

*I understand the benefits of cardio/aerobic exercise during concussion recovery and the potential negative impact of strict rest beyond 48-72 hours post-injury.*

<table>
<thead>
<tr>
<th>AT Response</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>31</td>
<td>57.4%</td>
</tr>
<tr>
<td>Agree</td>
<td>19</td>
<td>35.19%</td>
</tr>
<tr>
<td>Neutral</td>
<td>2</td>
<td>3.7%</td>
</tr>
<tr>
<td>Disagree</td>
<td>2</td>
<td>3.7%</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>
Table 9

I have the ability and resources to supervise cardio/aerobic exercise during athletics or practice (while an athlete is recovering from concussion).

<table>
<thead>
<tr>
<th>AT Response</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree (5)</td>
<td>25</td>
<td>46.29%</td>
</tr>
<tr>
<td>Agree (4)</td>
<td>19</td>
<td>35.19%</td>
</tr>
<tr>
<td>Neutral (3)</td>
<td>8</td>
<td>14.81%</td>
</tr>
<tr>
<td>Disagree (2)</td>
<td>2</td>
<td>3.7%</td>
</tr>
<tr>
<td>Strongly Disagree (1)</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Total responses</td>
<td>54</td>
<td>100%</td>
</tr>
<tr>
<td>Mean score (1-5)</td>
<td>4.24</td>
<td></td>
</tr>
</tbody>
</table>

Based on these responses, the overwhelming majority of ATs (93%) understand the benefit of exercise during acute concussion recovery, and 81% report having the resources needed to supervise aerobic activity at school. The AT tool also included an optional free text question that addressed potential barriers to supervising aerobic/cardio exercise during athletics or practice. While only 10 ATs were neutral or disagreed that they have the ability and resources to supervise aerobic activity, 12 left comments about specific barriers. Table 10 summarizes the comments received.

Table 10

If you do not have the ability and/or resources to supervise aerobic activity while an athlete is recovering from concussion, please explain any challenges or barriers such as appropriate space, equipment, staffing, time, or knowledge.

<table>
<thead>
<tr>
<th>AT categorized comments</th>
<th>Number of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understaffed/lack of time</td>
<td>7</td>
</tr>
<tr>
<td>Lack of resources for Middle School</td>
<td>1</td>
</tr>
<tr>
<td>Lack of equipment</td>
<td>3</td>
</tr>
<tr>
<td>-------------------</td>
<td>---</td>
</tr>
<tr>
<td>Lack of athlete participation</td>
<td>1</td>
</tr>
<tr>
<td>No issues or barriers</td>
<td>5</td>
</tr>
</tbody>
</table>

Clinic staff has had long-standing concerns that ATs are short-staffed and cover multiple programs or schools, and this has likely been intensified during the pandemic. While these responses confirmed the concerns of the clinic staff, these are not barriers that can be addressed with further collaboration or education. Clinic staff has received push back from ATs with concern that athletes should not exercise while still symptomatic or prior to full clearance, based on interpretation of UIL return to play guidelines (D. Salter, personal communication, June 2022). It was anticipated that free responses would include concerns regarding the guidelines or perceived risks of exercise during acute recovery that may be addressed with targeted education.

**Community Education**

The needs assessment tools included statements to assess AT and nurse perception of their own concussion knowledge base, and to identify preferences for future education methods and specific topics. This information was requested by the concussion clinic team so they can provide targeted education that builds further collaboration between staff and the community. AT Likert scale results indicated a strong comfort level in talking with parents/athletes about concussion signs and symptoms (mean = 4.78) and recovery (mean = 4.74). Nurse Likert scale results indicated comparatively less comfort level in talking with parents/athletes about signs and symptoms (mean = 4.12) and recovery (mean = 3.40). An additional question explored nurse knowledge of the benefits of aerobic exercise and early return to learn with similar ambiguity in ratings (mean = 3.44). The last statement for both tools assessed interest in targeted concussion education with a mean score of 4.13 for ATs and 4.45 for
nurses. Despite high self-ratings of knowledge level of concussion topics, AT responses indicate that the majority (76%) would like targeted concussion education. Nurse ratings indicate less confidence in their knowledge and provide a strong indication of the need for education, with 89% of nurse respondents indicating a desire for targeted education.

The final question for both tools asked for free text responses indicating any preferred educational methods and specific concussion topics. See Tables 11 and 12 for categorization of comments from ATs and nurses respectively.

Table 11

<table>
<thead>
<tr>
<th>AT free text responses - education</th>
<th>Number of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Categorized comments</strong></td>
<td></td>
</tr>
<tr>
<td>Comments re: education methods</td>
<td></td>
</tr>
<tr>
<td>Virtual presentation</td>
<td>11</td>
</tr>
<tr>
<td>In-person/on-site</td>
<td>5</td>
</tr>
<tr>
<td>Journal articles</td>
<td>7</td>
</tr>
<tr>
<td>Online modules</td>
<td>2</td>
</tr>
<tr>
<td>Comments re: education topics</td>
<td></td>
</tr>
<tr>
<td>Latest research, return to play</td>
<td>5</td>
</tr>
<tr>
<td>Latest research, return to learn</td>
<td>4</td>
</tr>
<tr>
<td>Sideline evaluation</td>
<td>1</td>
</tr>
<tr>
<td>Nutrition, supplements, meds</td>
<td>2</td>
</tr>
<tr>
<td>Management of prolonged recovery</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 12

Nurse free text responses - education

<table>
<thead>
<tr>
<th>Nurse categorized comments</th>
<th>Number of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Comments re: method for education</strong></td>
<td></td>
</tr>
<tr>
<td>Virtual presentation, include Q &amp; A</td>
<td>32</td>
</tr>
<tr>
<td>In-person, include discussion</td>
<td>10</td>
</tr>
<tr>
<td>On-line modules</td>
<td>10</td>
</tr>
<tr>
<td>Journal articles</td>
<td>6</td>
</tr>
<tr>
<td>Printable resources, Including parent handouts</td>
<td>4</td>
</tr>
<tr>
<td><strong>Comments re: educational topics</strong></td>
<td></td>
</tr>
<tr>
<td>Recovery, return to learn, return to play</td>
<td>16</td>
</tr>
<tr>
<td>Initial assessment and diagnosis, Early vs late symptoms</td>
<td>10</td>
</tr>
<tr>
<td>Parent education, resources, handouts</td>
<td>2</td>
</tr>
<tr>
<td>Specific ed for elementary school age</td>
<td>2</td>
</tr>
</tbody>
</table>

The majority of those leaving comments (58) cited in-person or virtual as their educational method of choice. Several respondents listed more than one option for potential educational methods, and the next most popular responses were journal articles (7 ATs, 6 nurses) and on-line modules (2 ATs, 10 nurses). In terms of educational topics, ATs asked for specifics including the latest research on exercise protocols, cognitive therapy, and nutritional supplements. Nurses consistently asked for education on initial assessment and diagnosis of concussion and the basics of return to learn and return to play recommendations.
Performance Monitoring

Compliance with Multimodal Assessment

Adherence to CDC recommendations was measured based on consistent compliance with four components of an objective multimodal assessment. Through the REDCap clinic database, reports were compiled to pull in the specific variables for each patient (n = 105), and a manual rate of compliance was calculated. Risk-factors for prolonged recovery include a history of attention deficit hyperactivity disorder (ADHD), learning disabilities (LD), anxiety, depression, previous concussions, and chronic headaches or migraines. A REDCap database report showed 100% compliance with collecting a history that includes each risk-factor for 105 athletes seen during the implementation period. Similarly, a database report confirmed that a Post-Concussive Symptom Inventory (PCSI) was collected at each visit for 100% of athletes seen since implementation of the new initiative. Also using the REDCap database, a report was compiled that showed that either ImPACT computerized cognitive testing or individualized neurocognitive testing with a neuropsychologist was performed at least once in 100 of the 105 patients (95%). Of the 100 patients, 87 had ImPACT testing and 13 had individualized testing with the neuropsychologist, most commonly due to concerns for learning disabilities or mental health issues that may impact standardized test performance (C. Austin, personal communication, July 2022). A manual chart review was done to assess for reasons that testing was not done for the remaining 5 athletes but no clear reason was documented. Computerized balance testing was also performed consistently, with 98% of athletes (103 out of 105) having balance testing performed at least one time. This variable is not collected in the clinic database, so a manual chart review of the electronic health record provided this information. The two athletes who did not have balance testing performed both had a spine injury and were wearing braces, which is a contraindication for testing.
Table 13

Adherence to multimodal assessment, n = 105 athletes

<table>
<thead>
<tr>
<th>Type of Assessment</th>
<th>Rate of compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk-factors (6) for prolonged recovery</td>
<td>100%</td>
</tr>
<tr>
<td>Post-concussive symptom inventory (PCSI)</td>
<td>100%</td>
</tr>
<tr>
<td>Cognitive testing</td>
<td>95%</td>
</tr>
<tr>
<td>Computerized balance assessment</td>
<td>98%</td>
</tr>
</tbody>
</table>

Satisfaction Ratings

A questionnaire was developed to assess parent satisfaction with the care provided to athletes with concussion. The non-validated tool was emailed to parents at the time of clinic discharge with 20 returned out of a total of 41 distributed (49%). Likert scale responses were overwhelmingly positive. Figures 4-7 illustrate frequencies of responses for each question.

Figure 4

*We were provided with education regarding concussion recovery and the benefits of exercise therapy, n = 20*
Figure 5

*The concussion team helped my child safely return to school and to sports/athletics, n = 20*

Figure 6

*The concussion team helped my child recovery from concussion, n = 20*
The mean score of the frequency of responses for each question was calculated with STATA (1= Strongly Disagree; 2= Disagree; 3= Neutral; 4=Agree; 5= Strongly Agree). Mean scores were 4.9, 4.9, 4.8, and 4.9 for the respective four questions. Questions 1, 2 and 4 had a standard deviation of 0.308 and a range of 4 to 5. Question 3 had a standard deviation of 0.523 with a range of 3 to 5. Mean scores exceed the clinic goal of a minimum of 80% satisfaction which is equivalent to 4 out of 5 on Likert scale ratings.

Of the 20 tools returned, 11 parents responded to the statement requesting suggestions for improvement. All comments were positive and several were extremely positive. For example, one parent stated “Excellent, thorough care along with the delightful and upbeat staff. (We) left feeling confident and the stress that comes along with an injury was alleviated due to the diligent care and communication with his high school athletic team. The concussion team are professionals who really care about their patients and their experiences, especially while under duress. I wish all interactions with medical professional could be this streamlined and convenient. We had no previous knowledge about concussion and now feel like we can not only notice the symptoms in ourselves, but other
teammates as well. It was a healing encounter all around.” Of the 11 free text responses, there was only one suggestion for improvement - “......we only wish we had known to come here first. Please advertise your services more broadly so other families can find you. I had to search for you. Thanks!” Of the 20 surveys returned, there were eight treadmill users and six of these parents (75%) left a (positive) comment. The remaining 12 surveys returned were from athletes who did not perform treadmill testing, and five of these parents (42%) left a (positive) comment.

A similar tool was developed to assess parent satisfaction for all other TBI/Concussion Clinic patients (non-athletes, all ages, with mild to moderate TBI) and was also set up to be e-mailed to parents at the time of clinic discharge. Questions mimicked those from the tool used for athletes to create the potential for comparisons between the two groups. The difference between the tools is in the initial question which is designed to assess if adequate education was provided. Rather than asking if education was provided on the benefits of exercise therapy, this tool asks if education regarding the diagnosis of TBI or concussion was provided. A total of 16 surveys were returned out of 62 (26%), and ratings were very positive. Mean scores were 4.7 (s.d. +/- 0.45), 4.6 (s.d. +/- 0.63), 4.2 (s.d. +/- 0.86), and 4.7 (s.d. +/- 0.49). Questions 1, 2 and 4 had a range of 4 to 5 while question 3 had a range of 3 to 5 which mimics the results of the previous tool. A total of five parents responded to the question requesting suggestions for improvement. Responses were all positive with three short remarks such as “thank you” and “friendly and informative.” There were two more detailed comments with high praise including one that named clinicians directly and described the team as “exceptional.”

While results from the general TBI/Concussion Clinic population were very positive, the mean scores from athlete parent responses were consistently higher. See Figure 8.
A chi-square analysis of the combined groups also demonstrated interesting results. Of the 20 athlete survey responses, 80% had a perfect score of 20 (Strongly Agree=5 for all four questions), while 50% of the 16 general survey responses had a perfect score of 20 which is approaching statistical significance with a p-value of 0.058. See Table 13.

### Table 13

**Comparison of Parent Satisfaction Tool Responses**

<table>
<thead>
<tr>
<th></th>
<th>Athlete tool</th>
<th>General tool</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total score = 20</td>
<td>16 (80%)</td>
<td>8 (50%)</td>
<td>24 (66.67%)</td>
</tr>
<tr>
<td>Total score &lt; 20</td>
<td>4 (20%)</td>
<td>8 (50%)</td>
<td>12 (33.33%)</td>
</tr>
<tr>
<td>Total</td>
<td>20 (100%)</td>
<td>16 (100%)</td>
<td>36 (100%)</td>
</tr>
</tbody>
</table>

*Note.* Chi-square analysis was performed of the responses with perfect scores, *p* = 0.058.
Based on this small number of parent satisfaction ratings, the parents of athletes who are part of the new initiative are more likely to give strongly positive ratings of approval with a perfect score of 20, compared with the parents of the general TBI/Concussion clinic patients. Interestingly, the results of the athlete parent questionnaires also suggest that parents of patients who had treadmill testing are more likely to leave a positive comment (75%) than parents of patients who did not have treadmill testing (42%). These numbers are very small and not clinically significant.

Outcome Evaluation

Impact of Treadmill Testing on Aerobic Activity

Of the 105 athletes seen, three were lost to follow-up, preventing final analysis in terms of exercise participation or time to recovery. The outcome evaluation will include the remaining 102 athletes of which a total of 26 (25.5%) performed treadmill testing at some point during their recovery period or at the time of final clearance. Of those 26 athletes, only seven had testing performed within two weeks, which is generally considered the acute recovery period. Of the 102 athletes, a total of 80 (78.4%) endorsed aerobic activity at home or school at least two times per week during recovery. Of the 26 athletes who had treadmill testing performed, 19 (73%) endorsed aerobic activity, and six out of seven athletes who had testing performed within two weeks of injury endorsed aerobic activity (86%). Of the remaining 76 athletes who did not have treadmill testing performed, 61 (80%) endorsed aerobic activity.

Treadmill testing did not have an impact on exercise participation based on chi-square analysis of a bivariate predictor (treadmill yes/no) on the bivariate outcome of whether or not the athlete participated in exercise outside the clinic (p-value = 0.424). See Table 14.
Table 14

Impact of Treadmill Testing on Aerobic Exercise

<table>
<thead>
<tr>
<th></th>
<th>No Treadmill Testing</th>
<th>Treadmill Testing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did Not Endorse Exercise</td>
<td>15 (19.74%)</td>
<td>7 (26.92%)</td>
<td>22 (21.57%)</td>
</tr>
<tr>
<td>Endorsed Exercise</td>
<td>61 (80.26%)</td>
<td>19 (73.08%)</td>
<td>80 (78.43%)</td>
</tr>
<tr>
<td>Total</td>
<td>76 (100%)</td>
<td>26 (100%)</td>
<td>102 (100%)</td>
</tr>
</tbody>
</table>

Note. Chi-square analysis used to determine differences in outcome, p = 0.424

While six out of seven athletes who had treadmill testing within two weeks of injury did endorse aerobic activity during the acute recovery period, the subgroups are very small and univariate analysis (Fisher’s exact) does not support a relationship between these two variables. See Table 15.

Table 15

Impact of Treadmill Testing (within 2 weeks) on Aerobic Exercise

<table>
<thead>
<tr>
<th></th>
<th>No Treadmill Testing</th>
<th>Treadmill Testing within 7 days</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did Not Endorse Exercise</td>
<td>21 (22.11%)</td>
<td>1 (14.29%)</td>
<td>22 (21.57%)</td>
</tr>
<tr>
<td>Endorsed Exercise</td>
<td>74 (77.89%)</td>
<td>6 (85.71%)</td>
<td>80 (78.43%)</td>
</tr>
<tr>
<td>Total</td>
<td>95 (100%)</td>
<td>7 (100%)</td>
<td>102 (100%)</td>
</tr>
</tbody>
</table>

Note. Fisher’s exact analysis used to determine differences in outcome, p = 1.000.

Unfortunately, the number of athletes who had treadmill testing at any time is very low (n = 26), and treadmill testing is not clinically useful if it is only performed outside the acute recovery period (two weeks) and/or performed only at the time of final clearance. Manual chart review demonstrated that 13 of the 26 athletes that had treadmill testing performed were cleared on the (only) day treadmill testing was performed, meaning full recovery was documented at the same visit. We would not expect treadmill testing done after two weeks or done at the time of clearance to impact the endorsement of exercise during acute recovery. As anticipated, univariate analysis of treadmill testing and the
endorsement of aerobic exercise at least twice weekly did not show a relationship between these two bivariate variables. Similarly, we would not expect treadmill testing done at the time of clearance to impact the incidence of persistent symptoms or days to recovery.

**Incidence of Persistent Post-Concussion Symptoms (PPCS)**

Of the 102 athletes, 69 recovered as expected and 33 athletes (32%) had PPCS, defined by symptoms for more than four weeks. This is higher than the benchmark of 20-30% cited in the literature, and may be attributable to the complexity and/or severity of concussions seen in this specialty clinic, including community referrals for patients who are not recovering as expected. To better understand this group of 102 patients, the prevalence of risk factors for prolonged recovery was calculated for the total population \( n = 102 \) and in athletes who developed PPCS. Of the 102 athletes, 34% have pre-existing anxiety or depression and 23% have ADHD or learning disabilities. In addition, 13% of the 102 athletes were documented as having pre-existing migraines or chronic headaches and 26% have a prior history of concussion. The prevalence of pre-existing ADHD or LD was similar to the overall prevalence when separated into those who developed PPCS and those who did not (23%, 21% and 25% respectively). The prevalence of pre-existing concussion was also similar between the three groups (26%, 24%, 27% respectively). However, the incidence of anxiety or depression in the group that developed persistent symptoms was 42% compared with 30% in the group that recovered within four weeks as expected. The incidence of pre-existing headaches in the PPCS group was 24% and only 7% in those that recovered as expected. This preliminary data suggests that pre-existing mental health issues and baseline headaches may be more significant risk factors for prolonged recovery in this group of athletes.

While not integral to the objectives of this program evaluation, this data may be further explored and compared to the prevalence of these risk factors in the general adolescent population. This
may lead to a better understanding of the prevalence of risk factors in the population of patients seen in this specialty clinic and the relationship to the incidence of PPCS. A deeper understanding of the relationship between pre-existing risk factors and PPCS may also help to direct future interventions.

**High-Risk Populations**

Based on the literature review, children from low socioeconomic families and Hispanic and other minority populations may be at risk for poor outcomes following mTBI. PPCS is an objective outcome with a national benchmark and will be used to compare outcomes among at-risk groups. Of the 102 athletes, 41% are uninsured or have Medicaid and this is used as a potential indicator of low socioeconomic status. The incidence of PPCS in this population is 26% which is lower than the overall group incidence of 33%. Of the 61 patients with private insurance, 22 (36%) developed PPCS.

The clinic sees a high volume of Hispanic patients and 39% of the 102 athletes are Hispanic, based on intake forms filled out by the parents (and collected in the database). A total of 27% of Hispanic athletes developed PPCS, which is similar but lower than the overall group incidence of 33%. Of the 62 non-Hispanic athletes, 12 endorsed a racial minority, leaving 50 White athletes. Of these, 20 developed PPCS which is 40% and considerably higher than the incidence in the total population or in the minority groups. Overall, vulnerable populations including Medicaid and uninsured patients and Hispanic children have similar or lower rates of PPCS compared to privately insured and White children, respectively, and compared to the total group of 102. See Figure 9.
Figure 9

*Incidence of PPCS with Comparison of At-Risk Groups*

![Bar chart showing the incidence of PPCS with comparison of at-risk groups.](chart.png)

**Impact of Exercise & Treadmill Testing on PPCS**

Of the 80 athletes that endorsed aerobic exercise, 53 recovered within four weeks and 27 (34%) had persistent symptoms or PPCS. Of the 22 athletes that did not endorse aerobic exercise, 6 (27%) had persistent symptoms. Based on univariate chi-square analysis of these two bivariate variables, exercise did not have an impact on the incidence of PPCS, \( p = 0.565 \). See Table 16.

Table 16

*Impact of Exercise on PPCS*

<table>
<thead>
<tr>
<th></th>
<th>Recovery within 4 weeks</th>
<th>Persistent Symptoms</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did Not Endorse</td>
<td>16 (23.19%)</td>
<td>6 (18.18%)</td>
<td>22 (21.57%)</td>
</tr>
<tr>
<td>Exercise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endorsed Exercise</td>
<td>53 (76.81%)</td>
<td>27 (81.82%)</td>
<td>80 (78.43%)</td>
</tr>
<tr>
<td>Total</td>
<td>69 (100%)</td>
<td>33 (100%)</td>
<td>102 (100%)</td>
</tr>
</tbody>
</table>

Note. Chi-square analysis used to determine differences in outcomes, \( p = 0.565 \)
Similarly, treadmill testing did not have an impact on the incidence of persistent symptoms or PPCS (p = 0.493). See Tables 17 and 18.

Table 17

**Impact of Treadmill Testing on PPCS**

<table>
<thead>
<tr>
<th></th>
<th>Recovery within 4 weeks</th>
<th>Persistent Symptoms</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Treadmill</td>
<td>50 (65.79%)</td>
<td>19 (73.08%)</td>
<td>69 (67.65%)</td>
</tr>
<tr>
<td>Treadmill</td>
<td>26 (34.21%)</td>
<td>7 (26.92%)</td>
<td>33 (32.35%)</td>
</tr>
<tr>
<td>Total</td>
<td>76 (100%)</td>
<td>26 (100%)</td>
<td>102 (100%)</td>
</tr>
</tbody>
</table>

*Note. Chi-square analysis used to determine differences in outcomes, p = 0.493*

Table 18

**Impact of Treadmill Testing (within 2 weeks) on PPCS**

<table>
<thead>
<tr>
<th></th>
<th>Recovery within 4 weeks</th>
<th>Persistent Symptoms</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Treadmill</td>
<td>64 (67.37%)</td>
<td>5 (71.43%)</td>
<td>69 (67.65%)</td>
</tr>
<tr>
<td>Treadmill within 2 weeks</td>
<td>31 (32.63%)</td>
<td>2 (28.57%)</td>
<td>33 (32.35%)</td>
</tr>
<tr>
<td>Total</td>
<td>95 (100%)</td>
<td>7 (100%)</td>
<td>102 (100%)</td>
</tr>
</tbody>
</table>

*Note. Fisher’s exact analysis used to determine differences in outcomes, p = 1.000*

As expected, treadmill testing did not have an impact on the incidence of persistent symptoms in this group, likely due to very small numbers as well as the late timing of treadmill testing, as previously described. It is unclear why athletes who endorsed aerobic exercise at least twice weekly during the recovery period did not have a decrease in persistent symptoms compared to those who did not endorse exercise. It is possible that athletes did not answer honestly or that exercise may need to be performed more than twice weekly to have an affect on the incidence of PPCS.
Impact on Time to Recovery

Time to recovery was recorded in days in the database based on the final visit date when recovery was documented. However, many athletes are noted to be recovered (symptom-free across all domains) some time prior to the clinic visit, according to a detailed symptom history. This means that the date of recovery recorded is not exact and dependent on timeliness of the clinic visit in relation to when symptoms resolved. Days to recovery is a continuous variable, so the first step was to perform an analysis of the number of days to recovery (mean, median, percentiles) for each group. A test of normality for the variable difference indicated that the data is significantly skewed (3.789), leading to the decision to perform a non-parametric rank sum analysis, rather than a T-test. Data was analyzed to evaluate the impact of exercise and treadmill testing on the outcome of days to recovery. The median days to recovery for the exercise and no exercise groups were 31.5 (interquartile range 20-54) and 32.5 (interquartile range 21 to 43) respectively, with a p-value of 0.974. Similarly, the median days to recovery for the treadmill and no treadmill groups were 32.5 (IQR 21-42) and 30.5 (IQR 20-56), with a p-value of 0.5803. Interestingly, treadmill testing did appear to have an impact on days to recovery when it was performed within two weeks, with median days to recovery 18 and 33 respectively, and it is approaching statistical significance ($p = 0.0697$). See Table 19.

Table 19

<table>
<thead>
<tr>
<th>Impact of Treadmill Testing within Two Weeks on Days to Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Median Days to Recovery</strong></td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>Treadmill Testing</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>No Treadmill Testing</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

*Note.* Rank sum analysis used to determine differences in outcomes, p-value = 0.0697

As previously noted, it was anticipated that treadmill testing was unlikely to impact days to recovery, due to the small numbers, and because 13 out of 26 of athletes performed treadmill testing (only) at the
time of full clearance. However, of the seven athletes that had treadmill testing within two weeks of injury, the median days to recovery was 18 days, compared to 33 days which is approaching statistical significance.

**Impact on Cognitive Scores**

Of the 102 athletes, 97 had a neurocognitive assessment at least one time, with 84 students performing ImPACT computerized cognitive testing and 13 athletes performing individualized neurocognitive assessment with the neuropsychologist. Individualized testing with the neuropsychologist was performed when an athlete was not recovering as expected, often times when mental health issues such as anxiety or depression were felt to be interfering with recovery (C. Austin, personal communication, May 2022). ImPACT computerized cognitive scores include four main components that are often affected by concussion – verbal memory, visual memory, processing speed, and reaction time. The composite scores for each component include a raw score and percentile, which provides a ranking of performance compared to peers. The difference in percentile scores from visit 1 to visit 2 and visit 1 to final visit were calculated for each of the 47 athletes who had two or more sets of scores to analyze. A test of normality for the variable difference demonstrated minimal skewing, allowing for the use of student T-tests to explore the relationship between aerobic exercise and cognitive scores. T-test analysis does not demonstrate a relationship between aerobic exercise and athlete scores on verbal memory, processing speed, or reaction time. However, there appears to be a positive impact (not statistically significant) of aerobic exercise on visual memory based on changes in scores from visit 1 to visit 2 (p = 0.0725), and a statistically significant improvement in visual memory scores between visit 1 and the final visit (p = 0.0327). See Tables 20 and 21.
Table 20

Impact of Exercise on Cognitive Scores Visit 1 -2

<table>
<thead>
<tr>
<th></th>
<th>No. Athletes</th>
<th>Verbal Mem Mean +/- Std. Dev</th>
<th>Visual Mem Mean, Std. Dev</th>
<th>Process Speed Mean, Std. Dev</th>
<th>Reaction Time Mean, Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not Endorse Exercise</td>
<td>7</td>
<td>31.28, +/-.32.02</td>
<td>-9.71, 33.41</td>
<td>2.57, 10.26</td>
<td>10.14, 15.46</td>
</tr>
<tr>
<td>Endorsed Exercise</td>
<td>40</td>
<td>17.15, 32.96</td>
<td>12.15, 28.28</td>
<td>15.2, 27.09</td>
<td>16.45, 32.19</td>
</tr>
</tbody>
</table>

*p-value (2-sided test)*

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p = 0.2990</td>
<td>P = 0.0725</td>
<td>P = 0.2331</td>
<td>P = 0.6162</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Student T-test used to compare means between the two groups.

Table 21

Impact of Exercise on Cognitive Scores Visit 1 - Final

<table>
<thead>
<tr>
<th></th>
<th>No. Athletes</th>
<th>Verbal Mem Mean, Std. Dev</th>
<th>Visual Mem Mean, Std. Dev</th>
<th>Process Speed Mean, Std. Dev</th>
<th>Reaction Time Mean, Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not Endorse Exercise</td>
<td>7</td>
<td>31.28, 32.02</td>
<td>-9.71, 33.41</td>
<td>2.57, 10.26</td>
<td>10.14, 15.46</td>
</tr>
</tbody>
</table>

*p-value (2-sided test)*

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p = 0.4961</td>
<td>P = 0.0327</td>
<td>P = 0.1514</td>
<td>P = 0.6027</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Student T-test used to compare groups.

While a relationship was not evident between the exercise group and visual memory, processing speed, and reaction time scores, it is interesting that in this small group of athletes, the group that exercised had a statistically significant difference in visual memory between visit 1 and the final visit.

Next, the relationship between treadmill testing (within two weeks) and cognitive scores was analyzed. A test of normality for the variable difference demonstrated minimal skewing, again allowing for the use of student T-tests. T-test analysis did not demonstrate a relationship between treadmill testing and athlete scores on verbal memory, visual memory, or reaction time based on changes from
visit 1 to 2. However, there appears to be a weak relationship (non-statistically significant) between treadmill testing and processing speed ($p = 0.0839$). See Table 22.

Table 22

*Impact of Treadmill Testing within 2 Weeks on Cognitive Scores Visit 1 - 2*

<table>
<thead>
<tr>
<th></th>
<th>No. Athletes</th>
<th>Verbal Mem Mean, Std. Dev</th>
<th>Visual Mem Mean, Std. Dev</th>
<th>Process Speed Mean, Std. Dev</th>
<th>Reaction Time Mean, Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No Treadmill</strong></td>
<td>43</td>
<td>17.58, 32.60</td>
<td>9.51, 31.05</td>
<td>11.34, 24.95</td>
<td>14.91, 29.12</td>
</tr>
<tr>
<td><strong>Treadmill</strong></td>
<td>4</td>
<td>37.25, 34.85</td>
<td>2.25, 4.42</td>
<td>34.5, 26.45</td>
<td>22, 45.82</td>
</tr>
<tr>
<td><em>p-value</em> (2-sided test)</td>
<td>P = 0.2568</td>
<td>P = 0.6458</td>
<td><strong>P = 0.0839</strong></td>
<td>P = 0.6587</td>
<td></td>
</tr>
</tbody>
</table>

Note. Student T-test used to compare groups.

T-test analysis did not support a relationship between treadmill testing and any of the cognitive score components based on changes from visit 1 to the final visit. See Table 23.

Table 23

*Impact of Treadmill Testing within 2 Weeks on Cognitive Scores Visit 1 - Final*

<table>
<thead>
<tr>
<th></th>
<th>No. Athletes</th>
<th>Verbal Mem Mean, Std. Dev</th>
<th>Visual Mem Mean, Std. Dev</th>
<th>Process Speed Mean, Std. Dev</th>
<th>Reaction Time Mean, Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No Treadmill</strong></td>
<td>43</td>
<td>22.32, 32.08</td>
<td>12.44, 30.92</td>
<td>14.58, 26.32</td>
<td>15.07, 30.40</td>
</tr>
<tr>
<td><strong>Treadmill</strong></td>
<td>4</td>
<td>39, 17.51</td>
<td>19, 33.01</td>
<td>37.75, 38.84</td>
<td>21.5, 23.39</td>
</tr>
<tr>
<td><em>p-value</em> (2-sided test)</td>
<td>P = 0.3140</td>
<td>P = 0.6882</td>
<td>P = 0.1119</td>
<td>P = 0.6836</td>
<td></td>
</tr>
</tbody>
</table>

Note. Student T-test used to compare groups.

As previously discussed, the total number of athletes who had treadmill testing within two weeks is very low (n = 7), and only four of those seven athletes had at least two visits with cognitive testing to compare.
Impact on Symptom Scores

Self-reported symptom ratings were collected for all 102 athletes at each visit. The Post-Concussive Symptom Inventory (PCSII) is the validated tool (Sady et al., 2014) that was used and it contains ratings across four domains – physical, sleep, emotional, and cognitive symptoms. A score is tabulated for each domain as well as a total score for each clinic visit. The tool includes a self-assessment of pre-injury (baseline) scores or ratings for each symptom, with a goal of teasing out post-injury symptoms related to concussion rather than non-injury factors. The difference in scores from visit 1 to visit 2 and visit 1 to final visit were calculated for each of the athletes that had at least two visits (n=71). A test of normality for the variable difference demonstrated minimal skewing, allowing for the use of student T-tests to explore the relationship between aerobic exercise and symptom scores as well as treadmill testing and symptom scores.

Table 24

Impact of Exercise on Symptom Ratings, Visit 1 to Visit 2

<table>
<thead>
<tr>
<th>No. Athletes</th>
<th>Total Scores Mean, Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not Endorse Exercise</td>
<td>11</td>
</tr>
<tr>
<td>Endorsed Exercise</td>
<td>60</td>
</tr>
</tbody>
</table>

*p-value (2-sided test) P=0.0281

Note. Student T-test used to compare groups.

Table 25

Impact of Exercise on Symptom Ratings, Visit 1 to Final

<table>
<thead>
<tr>
<th>No. Athletes</th>
<th>Total Scores Mean, Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not Endorse Exercise</td>
<td></td>
</tr>
<tr>
<td>Endorsed Exercise</td>
<td></td>
</tr>
<tr>
<td>Did not Endorse Exercise</td>
<td>11</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----</td>
</tr>
<tr>
<td>Endorsed Exercise</td>
<td>60</td>
</tr>
<tr>
<td><em>p</em>-value (2-sided test)</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Student T-test used to compare groups.

Table 26

**Impact of Treadmill Testing within 2 Weeks on Symptom Ratings**

<table>
<thead>
<tr>
<th></th>
<th>No. Athletes</th>
<th>Total Scores Mean, Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Treadmill</td>
<td>67</td>
<td>-24.60, 19.96</td>
</tr>
<tr>
<td>Treadmill</td>
<td>4</td>
<td>-4.50, 21.73</td>
</tr>
<tr>
<td><em>p</em>-value (2-sided test)</td>
<td></td>
<td>P=0.0554</td>
</tr>
</tbody>
</table>

*Note.* Student T-test used to compare groups.

Table 27

**Impact of Treadmill Testing within 2 Weeks on Symptom Ratings**

<table>
<thead>
<tr>
<th></th>
<th>No. Athletes</th>
<th>Total Scores Mean, Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Treadmill</td>
<td>67</td>
<td>-32.84, 20.03</td>
</tr>
<tr>
<td>Treadmill</td>
<td>4</td>
<td>-16.5, 16.86</td>
</tr>
<tr>
<td><em>p</em>-value (2-sided test)</td>
<td></td>
<td>P=0.1154</td>
</tr>
</tbody>
</table>

*Note.* Student T-test used to compare groups.

A larger decrease in the mean scores indicates more improvement in symptoms, and the tables actually illustrate a larger mean drop in symptom ratings in the non-exercise and non-treadmill groups. Potential reasons for this include the inequality in the group sizes of 67 and 4 in the non-treadmill and treadmill groups and 60 and 11 in the non-exercise and exercise groups. It is also important to note the
lack of timeliness in treadmill testing with the majority of testing completed outside the acute recovery period and/or at the time of full clearance. In addition, the exercise group is defined in the clinic database by the endorsement of aerobic exercise at least twice weekly, and this may not be sufficient to impact outcomes. The RCTs from the literature define exercise as occurring every day for at least 20 minutes.

Summary

A summary of key findings of this evaluation will be provided through responses to the formative and summative questions used to develop the evaluation.

1. Is the clinic receiving and accommodating three to four new athlete referrals per week, and scheduling evaluations in a timely manner?

There were 105 athlete referrals over the 8-9 month implementation period which is an average of approximately 12 referrals each month and three per week. This is consistent with the logic model target of 3-4 new athlete evaluations per week. Based on information obtained via staff interviews, the clinic can generally accommodate new referrals and schedule within one week, but this was challenging during the fall which is the busiest time of the year for sports-related concussions. In order to minimize days from injury to first visit and implement interventions in the acute recovery period, it would be beneficial for the team to plan for higher than average weekly referrals during the fall sports season, with increased resources to accommodate 4-5 new referrals per week.

Only five total referrals came from community ATs and nurses, but there was enthusiasm felt throughout the needs-assessment responses, and it will benefit the clinic to continue to collaborate with these stakeholders. Over time, as relationships are cultivated and referral processes are streamlined, this referral base is likely to grow and be a major contributor to patient volume. In addition, direct AT referrals for sports-related concussion may avoid the delays that can occur with ED or PCP referrals.
The majority of the remaining 100 referrals came from long-standing referral sources (ED and PCPs). The number of days from injury until the first visit ranges from 2 to 117 days with a median of 21 days. Of the 105 athletes, 23% were evaluated within the target of one week, 50% were within two weeks, and 16% were seen for the first time at 30 or more days post-injury. The new initiative target is to evaluate athletes within one week of injury, which allows for interventions to be implemented in the acute recovery period, as supported in the literature. In order to ensure that referrals are timely, the date of receipt of each referral must be tracked so that delays can be investigated. In addition, it may be helpful to provide community stakeholders including PCPs with direct contact information and the rationale for timely athlete referrals.

2. Are comprehensive evaluations including treadmill testing feasible for the clinic team?

Based on adherence rates of 95-100% for the four components of multimodal concussion evaluations, the clinic team is excelling in this area. However, only 25% of athletes had treadmill testing performed during at least one clinic visit. It is notable that treadmill testing was newly implemented at the start of the new initiative in September, with no time to develop a level of comfort with the protocol prior to data collection for this evaluation. In contrast, three out of the four components of multimodal evaluation (risk factors, symptom ratings, and balance testing) are long-standing assessments that were instituted years ago, during the initial development of clinic procedures (C. Austin, personal communication, July 2022). The fourth component of athlete evaluations is ImPACT computerized cognitive testing. Staff was trained and providers were certified as ImPACT consultants approximately six months prior to the start of the new initiative, and the team’s comfort level developed slowly over the next several months (C. Austin, personal communication, July 2022).

Similarly, the team’s level of competence and comfort with treadmill testing is likely to increase with time and repetition, and treadmill testing compliance will subsequently increase. It may also be helpful to explore barriers to treadmill testing with the team. Challenges reported include staff hesitation/lack
of comfort with treadmill procedures, insufficient time, athlete symptom burden and/or athlete reluctance, and lack of appropriate footwear. Regular review and discussion of the protocol including contraindications to testing may minimize staff concerns. Athletes are routinely scheduled for two-hour visits to incorporate all components of the assessment, including treadmill testing. The team may benefit from exploring the order and flow of multimodal assessments to optimize efficiency and allow sufficient time for treadmill testing. Staff has recently identified a solution for athletes that do not bring appropriate footwear, with a modification of the protocol (walking at an incline) and the use of hospital slip-proof socks.

3. What are the barriers to exercise therapy in the community?

Based on community surveys, the overwhelming majority of ATs (93%) understand the benefit of exercise during acute concussion recovery, and 81% report having the resources needed to supervise aerobic activity at school. However, 10 ATs were neutral or disagreed that they have the ability and resources to supervise aerobic activity, and 12 left comments about specific barriers which were related to insufficient staffing and equipment needed. ATs were also asked for feedback regarding specific educational topics, and the most common request was for the latest research on return to play guidelines and exercise protocols. The clinic team will benefit from increased collaboration with ATs including direct communication and targeted educational events that can be hosted by clinic staff. This will build a strong partnership and increase AT knowledge and confidence in supervising aerobic activity during recovery.

Another potential barrier to exercise therapy is lack of athlete motivation and this was cited by an AT in the free text comments. While this was not specifically explored or evaluated in this project, the theory behind treadmill testing in the clinic is to illustrate the importance of aerobic exercise to each athlete. By making treadmill testing a standard component of concussion evaluation, the team is setting an example for athletes and parents. Athletes who are symptomatic may be reluctant to exercise for the
first time at home or school, while doing it in a medical setting under direct supervision may alleviate concerns and/or increase motivation.

4. **Are athletes and parents satisfied with the active rehabilitation model of care?**

Athlete parent satisfaction ratings were overwhelmingly positive, with 80% of respondents giving a perfect score of 20, which is equal to a rating of 5/5 (Strongly Agree) for all four questions. Two of the four questions specifically address exercise education and safe return to sports, and the mean score for each of these two questions was 4.9. The mean score of responses of all four questions was 4.875. The tool also requested suggestions to improve care, and all responses were extremely complimentary. While numbers were small, parents of treadmill users were more likely to leave a positive comment (75%) than parents of non-treadmill users (42%). Survey ratings were compared to those from the general TBI/Concussion clinic population and univariate analysis demonstrated that athlete parents were more likely to give a perfect score of 20 (5 out of 5 for all four questions) compared to parents of general TBI/Concussion clinic patients ($p = 0.058$).

5. **Does treadmill testing in the clinic increase the rate of exercise participation outside the clinic? Is exercise therapy associated with decreased symptom ratings, decreased time to recovery, and decreased incidence of PPCS in this setting?**

In this specific population and setting, analysis did not show a relationship between treadmill testing and exercise participation outside the clinic. To better understand this finding, a manual chart review of the 26 athletes who performed treadmill testing was completed, including an investigation of the timing of testing. The objective of this initiative was to implement treadmill testing in the acute recovery period, ideally within one week of injury, as supported in the literature. Of the 102 athletes, 26 performed treadmill testing at some point including 13 (50%) that had treadmill testing only on the day of clearance. Of the 26, there were seven athletes that had treadmill testing within two weeks of injury, and three of the seven had testing only on the day of clearance. These leaves only four athletes who had
treadmill testing performed within two weeks of injury and prior to the day of clearance. Of the 102 athletes, 80 endorsed aerobic activity and 22 did not. We would not expect treadmill testing done after two weeks or done at the time of clearance to impact the endorsement of exercise during acute recovery. While treadmill testing on the day of full clearance is helpful to ensure that the athlete is symptom free with exertion, it cannot have an impact on measurable outcomes during the recovery period.

As anticipated, univariate analysis of the impact of treadmill testing on the endorsement of aerobic exercise did not show a relationship between these two bivariate variables. Similarly, we would not expect treadmill testing done at the time of clearance to impact the incidence of persistent symptoms, days to recovery, symptom ratings, or cognitive scores. As expected, analysis also did not support a relationship between treadmill testing and the incidence of PPCS. Days to recovery is another measurable outcome, and we measured the effect of treadmill testing (or exercise therapy) on days to recovery using rank sum, a non-parametric test. While no effect was seen on days to recovery when the exercise group (n = 80) or the total treadmill test group (n = 26) were used as the predictor, there appeared to be a positive impact of treadmill testing within two weeks (n=7) on median days to recovery. The median days to recover were 18 and 33 for the treadmill and non-treadmill groups respectively, p = 0.0697, which is approaching statistical significance.

The impact of predictors on mean change in cognitive scores was analyzed using a T-test and this did not show a positive relationship between treadmill testing within two weeks and any of the four cognitive scores, or total symptom ratings. However, the analysis did show a positive relationship between exercise and improvement in visual memory scores between visit 1 and 2 (p = 0.0725) and visit 1 and final visit (p = 0.0327), which was statistically significant.

Overall, data analysis did not support a relationship between exercise and multiple measurable outcomes, and the reasons are likely multi-factorial. Athlete endorsement of aerobic exercise at least
twice weekly during the recovery period was the categorical variable used to define the exercise group. This may have been a misclassification of this variable, meaning there is no clear guidance on the frequency of exercise required for improved outcomes, however the literature suggests daily exercise. In addition, adolescent self-report of exercise may have been influenced by the expectations of the clinic team and potentially over-reported. The exercise group (n = 80) compiled 78% of the total population and may not be an accurate reflection of aerobic activity outside the clinic. In addition, the data would be more valuable with comparable numbers in each group.

6. Is the clinic team providing multimodal care that follows the CDC guideline for management of mTBI in children (Lumba-Brown et al., 2018)?

The CDC guidelines for diagnosis and management of mTBI in children (Lumba-Brown et al., 2018) includes a detailed list of graded recommendations. This includes one Level A recommendation which is to provide comprehensive education and reassurance to the family. Parent satisfaction ratings indicate a very high approval of the education provided by the TBI/Concussion clinic with a mean score of 4.9 out of 5 for this specific question. Level B recommendations include assessing for a premorbid history of known risk factors for persistent symptoms. The confirmed adherence rate is 100% for assessment of six risk factors for prolonged recovery in the 105 athletes from this evaluation. Level B recommendations also include the use of a validated symptom scale to assess recovery. The TBI/Concussion clinic consistently uses the validated Post-Concussive Symptom Inventory (PCSI) (Sady et al., 2014) with 100% compliance for symptom inventory use at each visit for 105 athletes.

Level C recommendations include use of a validated cognitive test and balance testing to assess recovery. The TBI/Concussion clinic providers are trained and certified in ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) which is the is the only FDA-approved medical device to test cognitive skills following head injury (U.S. Food & Drug, 2016). Level C recommendations also include referral to a neuropsychologist for children with persisting cognitive problems, and a
neuropsychologist is a core member of the clinic team. Individualized neurocognitive assessments are done by the neuropsychologist for athletes with multiple risk factors for prolonged recovery and for those with persistent symptoms. The clinic has a 95% compliance rate for cognitive testing (either ImPACT or individualized) for the 105 athletes in this evaluation. Similarly, computerized balance testing is performed by the clinic AT using the BioSway tool for assessment of postural sway, with confirmation of 98% of the 105 athletes having at least one balance test performed.

7. **Is this model of care meeting the needs of community stakeholders and is it sustainable?**

Community stakeholders include parents, coaches, ATs, and nurses for the surrounding school districts. As previously described, parent satisfaction surveys support a high level of approval for the care provided by the TBI/Concussion clinic, and the only suggestion for improvement was to advertise services more broadly.

Through this evaluation, email distribution lists were created for 124 nurses and 132 ATs from schools throughout the service area. AT and nurse survey tools were developed and sent to these community stakeholders by the clinic AT and nurse. The response rate was encouraging with 59% and 42% of the nurse and AT surveys returned. The feedback was enthusiastic and indicated that these stakeholders are hungry for more knowledge and resources, and they value the collaboration with the clinic team. Current clinic processes include direct communication between the clinic nurse and the school nurse, and the clinic AT and the school AT following each visit. A plan of care for return to learn and exercise therapy are included in this communication. Clinic staff feels these processes are sustainable within their daily responsibilities (M. O’Connor, personal communication, May 2022; D. Salter, personal communication, May 2022).

While only five referrals were received from community ATs and nurses during the implementation period, this number is expected to increase significantly as the partnership between the clinic and the community is strengthened over time. However, the literature indicates that 15% of high school
students report having one or more concussions in the past year (cite), and there are over 20,000 high
school students in the Austin Independent School District with 3,000 concussions anticipated each year.
Austin ISD is one of many schools across the Central Texas region that is served by the TBI/Concussion
Clinic. The Logic Model indicates a long-term goal of 300-400 new athlete evaluations annually,
indicating that even with expected growth, the program cannot accommodate the community need
within the clinic walls.

**Interpretation**

*Aim 1: Perform an implementation evaluation of the initiative with a focus on the sustainability and impact of the program within the community.*

**Strengths**

Areas of strength in the clinic processes and community collaboration include a strong referral base from the ED and community pediatricians, providing an average of three new athlete referrals per week. Clinic visits are comprehensive, and processes have been standardized to allow for consistency in providing multimodal evaluations for every athlete. Community survey tools indicate that ATs and nurses are appreciative, supportive, and enthusiastic about collaborating to care for adolescents with concussion. AT responses indicate a desire to increase knowledge regarding exercise therapy and to overcome barriers to supervising athletes in the school setting. Parent satisfaction ratings suggest very high approval of the care provided by the team.
Opportunities for Growth

Opportunities for growth include increasing referrals from community ATs and nurses and ensuring that athlete referrals from long-standing sources are initiated as soon as possible following injury. The referral process and triage of referrals through the neurology EHR must be optimized to ensure the TBI/Concussion clinic staff has the opportunity to schedule athletes in a timely manner. Community support for the program is solid, and there is an opportunity to increase collaboration with ATs and nurses by building on established methods of communication and providing targeted resources and education to these stakeholders.

The impact of this new initiative on the community is in its early stages. The referral base will naturally grow over time through foundational community partnerships and collaborations that are in place. This specialty clinic is associated with the only Level I Pediatric Trauma Center in the region with a catchment area that includes 46 counties in Central Texas. However, the potential scale of this program has limits in terms of the volume of patients it can accommodate. An exciting challenge for the TBI/Concussion clinic team is to set an example for active rehabilitation and evidence-based concussion care that can be modified and integrated throughout community clinics and schools. A critical component of this objective is to educate community stakeholders in the benefits of active rehabilitation and potential harm that can result from outdated practices of rest and restriction. As active rehabilitation becomes a standard of care throughout Central Texas, referrals can be limited to patients with risk-factors for prolonged recovery and those who are not recovering as expected.
Aim 2: Provide performance monitoring of the care provided by the interdisciplinary team using quantitative and qualitative data.

Strengths

There are many strengths supported in the performance evaluation including very high satisfaction ratings from athlete parents with a mean score of 4.875 out of 5 for all responses. Ratings were compared to those from the general TBI/Concussion clinic population and chi-square analysis of the combined groups demonstrated that 80% of the athlete surveys had a perfect score of 20 (Strongly Agree=5 for all four questions), while 50% of the 16 general surveys had a perfect score of 20 which is approaching statistical significance ($p = 0.058$). Free text feedback was overwhelmingly positive, with comments that included “excellent, thorough care” and several parents directly named team members to thank them.

The TBI/Concussion Clinic provides a high-level of care that is evidence-based and follows CDC recommendations for comprehensive concussion management. The interdisciplinary team includes an AT and neuropsychologist, and athlete evaluations are routinely scheduled for two hours, with a focus on individualized education. The multimodal assessment includes standard processes that are consistently followed as well as objective, validated tools as recommended by the CDC. Performance monitoring demonstrated that the clinic team has a 95-100% adherence rate to the four components of multimodal assessment including risk factors, symptom scores, balance and cognitive testing. The support of leadership is evident in the dedicated, specialty staff, the equipment and resources, and time allotted for visits. Based on these findings, the clinic may be distinguished from other providers as a center of excellence.
Opportunities for Growth

In addition to the tools developed to evaluate parent satisfaction for this specific population, it would be beneficial to utilize standardized HCAHPS surveys to provide data that can be compared to other clinics and programs in the region and/or nationally. While the survey response rate of 49% is admirable, it may be helpful to consistently inform parents at the time of clinic discharge that they will receive an email survey from the Concussion team. In addition, survey tools should be translated into Spanish to ensure that feedback is collected from at-risk populations.

Aim 3: Evaluate the impact of active rehabilitation on outcomes in sports concussion recovery.

Strengths

The impact of treadmill testing and/or exercise on concussion outcomes was not evident in the small sample of data that was available. However, the clinic team has demonstrated that treadmill testing has tangible benefits as a component of active rehabilitation and can be successfully implemented in this setting. Through the implementation phase of this initiative, clinic providers and team members have put processes in place that are the foundation for sustainable growth of the program, with a consistent focus on active rehabilitation. Based on direct feedback, treadmill testing and exercise therapy are components of active rehabilitation that appear to be exciting to families and to community stakeholders. The parents of this specific population are extremely satisfied with care and more likely to leave a positive comment.

In addition, there seems to be something special about the seven athletes who had treadmill testing within two weeks. Despite these very small numbers, a non-parametric analysis showed that the treadmill testing group (n = 7) recovered within a median of 18 days while the non-treadmill group (n = 95) recovered in 33 days, which approaches statistically significance (p = 0.697). In addition, a T-test analysis of the mean change in visual memory scores of those in the exercise group (n = 80) compared
with those that did not endorse exercise (n = 22) showed a statistically significant impact of exercise on this outcome, \( p = 0.0327 \).

While the incidence of PPCS was not impacted by treadmill testing or endorsement of exercise in this small sample of athletes, the cost-benefit analysis (CBA) of a predicted decrease in PPCS remains useful. It provides a tangible picture of the value of the work being done by the clinic team to prevent PPCS in the population served. As the clinic database grows to include more patients who have followed a protocol for active rehabilitation, the data can be re-analyzed to measure a potential decrease in PPCS. The CBA supports that a predicted decrease in PPCS of 5% over one month (16 new referrals) is equal to $3970 saved. This tangible benefit to society was calculated based on the decrease in health care costs and school absences associated with one case of PPCS.

Based on analysis of the incidence of PPCS within disaggregated clinic data, the outcomes for vulnerable populations such as low socioeconomic status and Hispanic patients are comparable or slightly better than those of the general population and for privately insured and White athletes. Continuing to monitor the incidence of PPCS and other outcome measures within disaggregated clinic data is a starting point to ensure that the team is addressing potential health disparities in this population.

**Opportunities for Growth**

There is an opportunity for further exploration of the incidence of PPCS in the clinic population, and the impact of known risk-factors for prolonged recovery such as pre-existing headaches and mental health issues. It may be beneficial to understand the prevalence of risk-factors in the clinic population compared to the general adolescent population. In addition, an analysis of differences in the prevalence of risk-factors in those who develop PPCS and those who recover as expected may be helpful to direct future interventions.
Over time, the outcomes from this evaluation may be re-evaluated as referral processes are improved and the referral base grows. As more athletes are referred and scheduled in a timely manner, this will allow for the initial evaluation and treadmill testing to consistently occur in the acute recovery period which is integral to improving outcomes. If barriers to timely treadmill use in clinic can be addressed, the increased numbers may lead to more valuable and meaningful information. The level of comfort and confidence of the team in administering treadmill testing is expected to increase naturally with time and practice.

**Limitations**

This project is a program evaluation of a specialty clinic associated with an academic children’s hospital. Findings, interpretation, summary, and recommendations are specific to this setting and population and cannot be generalized to other clinics or settings. The parent satisfaction and community assessment tools have not been validated and were developed specifically for this initiative. While reliability and validity measures were in place, the outcome evaluation was limited by the scope of the data with the potential for missing or incorrect data in the database. Providers followed an agreed upon definition of functional recovery based on objective assessments, but there is room for subjectivity. The bivariate database variable of PPCS (persistent symptoms greater than four weeks) also required a potentially subjective decision by the provider, as concussion symptoms can be related to non-injury factors. Similarly, the endorsement of aerobic exercise at least twice weekly was based on a conversation between the provider and athlete, rather than an anonymous self-report.

**Funding**

There was no dedicated funding for this project.
Recommendations

Implementation Evaluation

- Track and collect the date each referral was received, allowing for root cause analyses of delays in the referral process and/or delays in scheduling.
- Provide community PCPs with information regarding the TBI/Concussion clinic services and education on active rehabilitation including the value of exercise in the early recovery period.
- Provide community PCPs and other referral sources the direct fax number for TBI/Concussion Clinic which feeds into the Physical Medicine & Rehabilitation “bucket” in the EHR.
- Provide community PCPs with a direct line of communication to the TBI/Concussion Clinic nurse and provider for questions/concerns regarding potential concussion referrals.
- Routinely monitor the current ED referral process to identify delays in referrals or patients that were seen in the ED but not referred via standard process.
- Provide community ATs a direct line of communication to the TBI/Concussion clinic AT for referrals and for questions/concerns.
- Provide community nurses a direct line of communication to the TBI/Concussion clinic nurse for referrals and for questions/concerns.
- Provide community ATs and nurses with specific information regarding the referral process for medical evaluation and the importance of timely referrals.
- Continue to provide community ATs and nurses with direct communication following each student athlete evaluation, including specifics of academic recs and exercise therapy.
- Provide community ATs and nurses with targeted educational resources to build knowledge base and improve collaboration, based on community needs assessment responses.
  - Offer in-person or virtual educational sessions annually and consider increasing to quarterly.
  - Include specific topics requested including sideline eval, initial assessment and diagnosis of concussion, return to play and exercise protocols, return to learn/academic recommendations, nutrition and supplements, tips for prolonged recovery.
  - Provide CDC resources including Heads-Up website, and online modules for coaches, ATs, and nurses.
  - Offer current journal articles on the latest evidence for exercise therapy.

Performance Monitoring

- Highlight the TBI/Concussion Clinic’s strengths including extended time spent with families to allow for objective, multimodal assessment per CDC guidelines as well as individualized education.
- Highlight the TBI/Concussion Clinic’s strengths including adherence to a high standard of care including 100% compliance with evaluation of risk factors and validated symptom inventory at every visit.
- Highlight the TBI/Concussion Clinic’s strengths with a highly specialized staff that includes a neuropsychologist and providers certified in ImPACT neurocognitive testing, and an interdisciplinary approach allowing for cognitive assessment in 95% of athletes seen.
- Highlight the TBI/Concussion Clinic’s strengths with a specialized staff that includes an AT, and an interdisciplinary approach that allows for objective balance testing in 98% of athlete visits.
- Highlight the TBI/Concussion Clinic’s strengths including 98% satisfaction ratings (mean = 4.875 out of 5-point Likert scale) with extremely complimentary free response feedback.
Consider utilizing existing HCAP standardized satisfaction surveys in addition to the tool developed specifically for this clinic.

- Ensure the team is meeting the needs of high-risk populations such as Hispanic families by translating all tools and handouts into Spanish.
- Continue to provide the team with regular feedback from satisfaction survey responses to allow for quality improvement measures to occur in real-time.

**Outcome Evaluation**

- Provide the TBI/Concussion Clinic team with further education, review of protocols, and Q & A regarding treadmill testing.
- Provide the clinic team with information regarding the rationale for utilizing treadmill at the first visit and within one week of injury.
- Further explore barriers to timely treadmill testing and team member’s hesitation to implement at the first clinic visit.
- Continue to collect and analyze data to explore outcomes specifically for exercise and treadmill use, as more athletes are seen and evaluated during the acute recovery period.
- Redefine the database variable for endorsement of exercise to be consistent with the literature (at least 3x/week or daily exercise).
- Continue to collect disaggregated data for race/ethnicity/gender expression/socioeconomic status and evaluate the incidence of PPCS and other outcomes in vulnerable groups compared with the general clinic population and groups that are not at increased risk for poor outcomes.
- Further explore the impact of risk factors for prolonged recovery (pre-existing headaches, mental health issues) with comparisons of prevalence in those that develop PPCS and those that do not. This will be helpful to direct future interventions.
- As more data is collected, the cost-benefit-analysis can be used to highlight the financial benefit to society of decreasing the incidence of PPCS.

**Conclusion**

It is well-supported in the literature that active rehabilitation can decrease PPCS and improve outcomes when it is implemented early in the recovery period. This comprehensive evaluation illustrates that active rehabilitation is impactful in this specialty clinic within an academic children’s hospital. The challenge is replicating this concept outside the quaternary setting where it can positively impact outcomes for thousands of adolescents every year in the surrounding community. The model for active rehabilitation will look different in community clinics and schools, but it begins with the example set in this specialty clinic for evidence-based practice. Through the development of strong community partnerships, collaboration, and education, the traditional recommendation of rest and restriction will fade from practice. The goal is to bring evidence-based concussion care to the larger community where
it can be accessed by all adolescents at the initial health care encounter, with more potential for impact on populations at risk for poor outcomes and/or prolonged recovery.
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Aims & Objectives

1. **Aim:** Perform an implementation evaluation of the initiative with a focus on the sustainability and impact of the program within the community.
   **Objectives:**
   a. Evaluate the effectiveness of collaboration with community stakeholders (public school nurses and athletic trainers) to secure new referrals based on stakeholder self-reported knowledge of referral process and number of new referrals.
   b. Evaluate the effectiveness and timeliness of the referral and triage/scheduling processes utilizing database measure of time from injury to first visit.
   c. Evaluate barriers to implementation of aerobic exercise through community needs assessments with private soccer club and public-school athletic trainers.
   d. Evaluate strengths and weaknesses of the program and ability to meet stakeholders’ needs through staff interviews and community assessment tools.

2. **Aim:** Provide performance monitoring of the care provided by the interdisciplinary team using quantitative and qualitative data.
   **Objectives:**
   a. Develop RedCap parent satisfaction tools and process to collect and analyze data.
   b. Review data regularly to inform team and allow for QI measures to occur in real-time.
   c. Implement a process to track adherence to pre-determined clinic goals that are aligned with CDC guidelines for multimodal assessment of mTBI.
   d. Provide stakeholders with performance data to distinguish program from other providers.

3. **Aim:** Evaluate the impact of active rehabilitation on outcomes in sports concussion recovery.
   **Objectives:**
   a. Measure the impact of treadmill testing on athlete participation in exercise therapy (at home or school) using self-reported participation rates.
   b. Perform data analysis to evaluate the impact of treadmill testing and/or exercise therapy on cognitive scores (ImPACT testing), and Post-Concussive Symptom Inventory (PCSI) ratings.
   c. Perform data analysis to evaluate the impact of treadmill testing and/or aerobic exercise on time to recovery and the incidence of persistent post-concussive symptoms (PPCS).
   d. Provide a cost-benefit analysis of the benefit of predicted and actual decrease in PPCS.
   e. Provide a comparison of groups to include outcomes for vulnerable populations.
## Data Management Plan

Program Evaluation of a New Initiative in an Interdisciplinary Pediatric Concussion Clinic: Active Rehabilitation Following Sports Concussion

### Data Management Plan

<table>
<thead>
<tr>
<th>Aim 1</th>
<th>Description</th>
<th>Type</th>
<th>Source</th>
<th>Timeline</th>
<th>Analysis</th>
<th>Display</th>
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<tbody>
<tr>
<td></td>
<td>Evaluate processes &amp; community collaboration</td>
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</tbody>
</table>
| 1.1   | Collaboration, securing referrals | Quantitative | Database, AT & nurse tools | Collect data in April | Analyze data in May | 1. STATA calc of #referrals by source  
2. Frequency of responses and mean scores of 4 related questions for each tool  
3. Manual categorization of comments, quotes | 1. Table  
2. Table  
3. Table |
| 1.2   | Clinic ability to schedule and provide treadmill testing | Mixed | Database, Staff interviews | Ongoing data collection Interviews in April/May | 1. STATA calc of median # days to visit 1  
2. Percentage of athletes using treadmill  
3. Manual categorization of staff input, comments | 1. Box plots  
2. Narrative  
3. Narrative |
| 1.3   | Barriers to aerobic exercise in community | Mixed | AT tool | Collect data in April Analyze data in May | 1. Frequency of responses and mean scores of 2 related questions for AT tool  
2. Manual categorization of comments, quotes | 1. Table  
2. Table |
### Aim 2: Provide performance monitoring

| 2.1 | Adherence to national guidelines – Risk factors, PCSI, ImPACT, Balance testing | Quantitative | Database | Ongoing data collection & review | 1. REDCap report with manual calc of percentage of athletes that had each of the assessments performed 2. Manual chart review to determine if balance testing was performed | 1. Table 1 2. Table 1 |


### Aim 3: Evaluate impact on concussion recovery & financial benefit of decreased PPCS

| 3.1 | Impact of treadmill on exercise participation | Quantitative | Database | Ongoing data collection Data analysis in June | 1. STATA calc of univariate analysis (Chi-square or Fisher’s exact) | Tables: Treadmill use - impact on multiple outcomes (exercise, symptom ratings, cog scores, days to recovery, PPCS) |

| 3.2 | Impact of treadmill and exercise on PCSI & Cog scores | Quantitative | Database | Ongoing data collection Data analysis in June | 1. STATA calc of mean change from visit 1 to subsequent visits 2. Non-parametric (rank sum) if skewed or T-test if not skewed |
## 3.3 Impact on PPCS

**Impact on PPCS (yes/no); Impact on time to recovery (days)**

**Quantitative**

**Database**

**Ongoing data collection**

Data analysis in June

1. STATA calc of univariate analysis (Chi-square or Fisher’s exact)
2. STATA calc of mean days to recovery (median if skewed)
3. Non-parametric (rank sum) or T-test

Tables: Exercise participation - impact on multiple outcomes (symptom ratings, cog scores, days to recovery, PPCS)

## 3.4 Determine financial cost to society of PPCS, school absences, psychotherapy referrals

**Quantitative**

**Literature & community data**

**Lit review & CBA (predicted) done during planning stages**

1. CBA done with predicted 5% decrease in PPCS in preparation of evaluation

Narrative description

## 3.4a Determine financial benefit to society of decreased PPCS based on actual decrease

**Quantitative**

**Database**

**Ongoing data collection**

1. STATA calc of incidence of PPCS in treadmill/exercise group compared with non-treadmill/exercise group
2. Apply percentage decrease to CBA data for society cost of PPCS, missed school days, referrals for psychotherapy

Narrative description with future application of percentage decrease to CBA data, as more patient data becomes available.

## 3.5 Provide a comparison of groups to include outcomes for

**Quantitative**

**Database**

**Ongoing data collection**

Data analysis in July

1. REDCap report of disaggregated data and PPCS and

Narrative description

Bar graph
| vulnerable populations |  |  |  | manual calculation of percentages |