2020

Use of Subthreshold Aerobic Activity Versus Rest Alone for Treatment in Patients Diagnosed with a Concussion

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USE OF SUBTHRESHOLD AEROBIC ACTIVITY VERSUS REST ALONE FOR TREATMENT IN PATIENTS DIAGNOSED WITH A CONCUSSION

A MASTER'S CAPSTONE PROJECT

SUBMITTED TO THE GRADUATE FACULTY

OF THE GRADUATE SCHOOL

BETHEL UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF SCIENCE IN ATHLETIC TRAINING

MAY 2020

BETHEL UNIVERSITY

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May 2020

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Abstract

Background: Treatment of concussions has historically included rest until asymptomatic, but the latest concussion consensus statement questioned the effectiveness of this treatment. Ambiguity continues to prevail amongst sports medicine practitioners on whether rest or subthreshold aerobic activity will aid in quicker symptom resolution and shorter duration of the injury.

Purpose: Do patients, who have been diagnosed with a concussion, have decreased symptoms and a quicker return-to-play when subthreshold aerobic exercise is used in their treatment versus rest alone?

Results: Twenty-five scholarly articles were analyzed using a matrix format and were evaluated with the PEDro Scale, CASP Questionnaire, or a series of four questions. Twenty-three of the 25 studies either recommended subthreshold activity, demonstrated that it was safe, found participating in an aerobic intervention was not more detrimental than rest, or concluded rest to be harmful in concussion rehabilitation. Three studies recommended rest as a quality intervention for concussion treatment.

Conclusion: The use of subthreshold aerobic activity as a treatment for patients diagnosed with a concussion is safe and more effective for resolution of symptoms and return to baseline activities than rest. Instead of waiting for symptoms to resolve, an athlete should be started on a protocol introducing subthreshold aerobic activity as soon as a few days post-injury. If treatment has already been delayed, and the patient has been symptomatic for months, they will still benefit from subthreshold aerobic activity.

Implications for Research and Practice: These findings challenge the current clinical practice of rest for post-concussion treatment. The literature encourages athletic trainers and physicians who manage concussions to adopt a treatment protocol with subthreshold aerobic activity. Further research is needed on *excellent* quality articles with a larger number of participants and investigating when subthreshold aerobic activity should be initiated post-concussion for optimal results.

Keywords: concussion, subthreshold aerobic activity, physical activity, rehabilitation, rest

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Chapter I: Introduction

Over the past decade, sports-related concussions (SRC) have become a topic of interest around the world. As many as 2.8 million traumatic brain injuries are reported in the United States each year alone, and of this 2.8 million, a large majority of the injuries are classified as mild traumatic brain injuries (mTBI) (Gupta, Summerville, & Senter, 2019). The term concussion is used interchangeably with mTBI, and it occurs when biomechanical forces are applied to the skull causing the brain to accelerate and decelerate rapidly. This injury may result when an athlete is hit directly in the head, neck, or other part of the body. The force that is applied when hit or rapidly moved is transferred to the brain ultimately causing the injury (McCrory et al., 2017; Broglio et al., 2014). In addition, Register-Mihalik et al.'s study concluded that females are at greater risk for sports-related concussions and tend to have more symptoms with increased severity and prolonged recovery in comparison to males (Register-Mihalik, Vander Vegt, Cools, & Carnerio, 2018). Other populations and demographics have not been studied enough to determine if they too are at a higher risk for acquiring a concussion or enduring a prolonged recovery. Moreover, clinicians recognize concussions as one of the most complex injuries to manage in sports medicine. Sport medicine clinicians understand clinical judgement needs to be made for each case since there is no gold standard test that is able to diagnose a concussion with absolute certainty (McCrory et al., 2017; Broglio et al., 2014).

When an athlete is suspected to have a SRC, he or she is evaluated based on "clinical symptoms, physical signs, cognitive impairment, neurobehavioral features, and sleep/wake disturbances" (McCrory et al., 2017, p. 3). Symptoms may include, but are not limited to, headache, dizziness, confusion, loss of consciousness, irritability, gait unsteadiness, slowed reaction times, or drowsiness. If the potential for a concussion diagnosis exists, the athlete should be removed from play and entered into a protocol to further determine if a SRC is the official diagnosis. This is necessary as concussion symptoms can progress over time. Once an athlete is diagnosed with a concussion, the treatment process begins. Return-to-play and school accommodations should be discussed at the first appointment with the health care provider. Education should be given to the patient and their family to make sure everyone has an understanding of the seriousness of a concussion injury. Red flags and expectations going forward are important topics to discuss at the initial appointment. For many clinicians, their first recommendation is for the athlete to rest. Theoretically, this allows the patient to calm down their symptoms and decrease brain energy demands to encourage healing. Rest has not yet been proven to achieve healing in all SRC cases, and recently, clinicians are challenging the theory by suggesting their patients be more active while remaining at a subthreshold activity level during the acute phase (24-48 hours) of healing (McCrory et al., 2017). Subthreshold activity is defined as an exercise that does not produce symptoms and is objectified as 80 percent of the patient's maximum heart rate (Leddy et al., 2019). Evaluating rest versus subthreshold aerobic activity for symptom resolution and return-to-play status is the subject of this literature review.

Other injuries that affect the central nervous system have seen improvements in recovery time and symptom severity when aerobic activity is introduced. Low to moderate activity has shown to aid with neural regeneration after a traumatic event, therefore sports medicine clinicians are interested in the effects of this type of activity in patients with SRC (Micay, Richards, & Hutchison, 2018). The expert panel at the latest concussion consensus conference, the 2017 Concussion in Sport Group, is taking a particular interest in how rest and exercise can affect concussion recovery. Their points of view regarding concussion treatment continue to expand, and they now state that after the first 24-48 hours post-injury, rest is not necessarily beneficial. This leads to the question, what is beneficial after that phase? (McCrory et al., 2017). The question for this Critical Review of the Literature is: Do patients, who have been diagnosed with a sports-related concussion, have decreased symptoms and a quicker return-to-play when subthreshold aerobic exercise is used early in their treatment versus rest alone?

Statement of Purpose

The purpose of this paper is to evaluate whether rest or subthreshold aerobic activity provides greater benefits for patients diagnosed with a sports-related concussion shortly after their initial injury. To determine the effectiveness of both treatment options, specific outcomes will include symptom rating scores as well as the duration until the patient is cleared to return-to-play. Preliminary research has been completed on this topic, but concrete, consistent evidence seems to be minimal, which may be preventing clinicians from adopting the new protocol.

Need for a Clinical Review

According to the 2017 Concussion in Sports Group, concussions typically recover in 10-14 days, which is similar to the recovery time of a minor musculoskeletal injury. This may be influential in concussions not being seen as high-risk situations needing better outcomes and therefore not studied (McCrory et al., 2017). Nonetheless, post-concussion syndrome, a prolongation of symptoms per result of a SRC, can occur. If adding subthreshold aerobic activity to a patient's treatment plan will decrease the likelihood of a prolonged recovery, patients will potentially experience less academic and social dysfunction (Leddy et al., 2019). Further discovery of treatment options is needed to not only return young patients back to sport in a timely manner but to return them to a prior level of function and life quality as quickly as possible.

Rest remains to be the most common method to treat concussions as it is a precautionary measure. The brain can be a challenging structure to understand. It is mysterious, and concussion treatments, up until recently, have not been challenged. Rest has been the accepted method of treatment as it seemed to help the majority of patients, and knowledge of concussions was limited. Just as an ankle sprain is treated with rest, the same healing benefits are thought to be true for the brain because the patient is allowing the brain to use more energy toward healing and less towards completing daily tasks. Also, the patient tends to feel better when resting as symptoms are relieved. However, the benefits of rest as a treatment for concussions is not significantly backed by evidence. In fact, the "rest-is-best approach was based on animal research and consensus guidelines" (Leddy et al., 2019, p. 320). This is why researchers such as Leddy et al. (2019) have begun to investigate if rest is truly the best treatment option for SRC. Undeniably, rest will be needed in some capacity after injury, but the exact duration is not known (McCrory et al., 2017). Also, avoiding exercise while still symptomatic has not been shown to accelerate the recovery process whereas subthreshold exercise has shown benefits in improving physical, psychological, and academic outcomes in patients (Grool et al., 2016). Increased knowledge on aerobic activity in comparison to rest alone should guide treatment of concussions to be more effective than current recommendations, and perhaps reduce the duration of concussive symptoms in athletes.

Significance for Athletic Training

Athletic trainers (ATs) are individuals who work under a physician, and they provide many services in a variety of settings. ATs provide "primary care, injury and illness prevention, wellness promotion and education, emergent care, examination and clinical diagnosis, therapeutic intervention and rehabilitation of injuries and medical conditions" (NATA, 2019, n.p.). Athletic trainers are well educated in concussion management and are usually the first to evaluate an acute concussion. ATs manage concussions as they feel comfortable and guide the athlete through the return-to-play process (Broglio et al., 2014).

Part of an athletic trainer's education includes concussion management, however, distinct differences exist in how much each AT knows about concussions, as concussion research has exploded over the past decade. Statements regarding protocols are important, allowing all practitioners to understand their role as well as inform how to treat certain illnesses and injuries. However, the concussion protocol has not been updated by the National Athletic Trainer's Association (NATA) since 2014 (Broglio et al., 2014). Six years later, this position statement is due for an update as the concussion consensus conference occurs every four years. The conference last took place in 2016, and the next concussion conference is to be held in Paris at the end of October in 2020 (6th International Consensus Conference on Concussions, 2020). Some Information in the NATA position statement is not as relevant as it once was since many discoveries surrounding concussions have been made in recent years. For example, the NATA position statement on concussion protocol still includes the suggestion to treat concussions with rest until the patient is asymptomatic (Broglio et al., 2014). This variance is why conclusive results on whether rest or aerobic activity show greater benefits for treatment after the initial injury could be very helpful. Overall, this review is intended to contribute to the existing research surrounding concussion rehabilitation in hopes of positively impacting people who are diagnosed with a concussion.

Chapter II: Methods

This chapter describes the processes and methods used to examine articles on the effectiveness of subthreshold aerobic activity within concussion rehabilitation. Search strategies, inclusion and exclusion criteria, number and types of studies selected, and criteria used for evaluating studies are discussed below.

Search Strategies

The majority of articles for this Critical Review of the Literature came from using CLICsearch, a collective database provided to all students at Bethel University, MN. Other articles were found using PubMed and Google Scholar databases. Additional studies were discovered by looking at the reference page of high-quality articles previously located and through word of mouth from medical professionals. Keywords used during the searches included “concussion,” “activity,” “rehabilitation,” “physical,” “subthreshold,” “rest,” “pediatric,” “youth,” and “aerobic.” Initial results yielded between 852 to 973 articles. Additional keywords, as listed above, were added to the search to aid in narrowing the number of hits. The word “and” was disregarded because it was broadening the search and yielding unrelated articles. Furthermore, CLICsearch has a function where the researcher can choose to include only peer-reviewed articles. This function was included in all searches to help narrow the findings. After these modifications, the number of articles was reduced to 61, but an additional 36 articles were disregarded due to being irrelevant or not abiding by the set inclusion and exclusion criteria. This meant 25 articles were able to be used in this Critical Review of the Literature. All articles were published between the years of 2012 and 2019.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were established so that recent, relevant articles would be gathered and utilized for this literature review. In order for an article to be included, it had to have subthreshold aerobic activity, physical activity, or rest as an intervention for concussion rehabilitation. All populations and ages were included, and all studies had to be conducted within the past decade. Furthermore, no restrictions on the type of article design were taken into consideration.

Exclusion criteria eliminated articles with interventions other than subthreshold aerobic activity, physical activity, or rest for a concussion. Articles in languages other than English were excluded as well as studies that required a purchase to read beyond the abstract. No study conducted more than 10 years ago was considered for this literature review.

Number and Types of Articles

Twenty-five articles were selected based on the inclusion criteria. Many of the articles were evaluated using the PEDro Scale and Critical Appraisal Skills Programme (CASP) Questions (The George Institute for Global Health, n.d.; Raab & Craig, 2016). The PEDro scale and CASP questionnaire forms are included in Appendix B for additional review. Systematic reviews, in particular, were evaluated using a series of four questions: “Is the clinical question focused?”, “Was the literature search thorough and exhaustive?”, “Are the included studies of high quality and valid?", and "Is the selection of the included studies reproducible?" (Raab & Craig, 2016, p. 81). These evaluations helped to determine the quality of each article. All studies included in this review were granted quality status of either *excellent*, *good,* or *fair*. If the article was evaluated via the PEDro scale, a score of nine or ten was considered *excellent*, six through eight was considered *good*, and below six warranted a quality status of *fair* (Hariohm, Prakash, & Saravankumar, 2015). If the CASP Questionnaire or series of four questions was used, the determination of the quality of the article was more subjective to the researcher. The CASP Questionnaire does not have clear guidelines that determine the quality of the article. Instead, the more times "yes" can be answered to the questions or the "no" can be explained, the higher the quality the article will be. The ability to answer "yes" to all questions when using the four-question method means that the article can be considered of *good* quality. When questions did not have an answer, the level of quality was affected negatively (Raab & Craig, 2016). Furthermore, the level of evidence for each article was determined by using the "Hierarchy of Evidence for Intervention Studies" chart (Fineout-Overholt, Melnyk, Stillwell, & Williamson, 2010). This chart is located in Appendix B. Levels I, II, III, and IV were present amongst the various articles. Each level represents a different article design. Level I represents systematic reviews; level II represents randomized control trials; level III represents controlled trials without randomization; and level IV represents case-control and cohort studies. There were three articles for level I, eleven articles for level II, three articles for level III, and eight articles for level IV.

Table 1 provides a clear representation of the level of evidence and quality for each article included in the literature review.

Table 1: Level of Evidence and Quality of Included Articles

Level of Evidence	Excellent Quality	Good Quality	Fair Quality	Total Number of Articles
I	0	3	0	3
II	3	7	1	11
III	0	3	0	3
IV	0	8	0	8
Total				25

Criteria for Evaluating the Studies

Each included study was placed into a matrix developed by the Bethel University Graduate Nursing Program. For each study, information recorded into the matrix included citation, design methodology, purpose, sample/setting, design instruments, results, and recommendations. Subheadings for "level of evidence" and "quality of the article" were also present in the matrix under the sample and setting column. As stated above, the level of evidence and overall quality were evaluated using the PEDro Scale, CASP Questionnaire, or a series of four questions (The George Institute for Global Health, n.d.; Raab & Craig, 2016). Based on the "Hierarchy of Evidence for Intervention Studies" chart, a lower level of evidence number generally implies that the article would be of higher quality (Fineout-Overholt et al., 2010). Good-quality articles clearly communicate their study to their population, contain correlating findings to other high-quality, current literature, include a strong sample size, and have a control group represented in their research. On the contrary, low-quality articles oftentimes have missing information in its research, lack a consistent baseline demographic group, and do not produce conclusive results.

Summary

Articles on the effectiveness of subthreshold aerobic activity as an intervention for patients diagnosed with a concussion were researched using multiple databases. Many articles were determined useful according to the designated inclusion and exclusion criteria. In total, 25 articles were found and placed in a matrix format. The level of evidence and level of quality were then reported for each article.

Chapter III: Literature Review and Analysis

Synthesis of Matrix

The intent of chapter three is to review and analyze the literature from 25 scholarly, current articles with the goal of answering the research question presented in chapter one. To accomplish this goal, the matrix format developed by the Bethel University Graduate Nursing Program was utilized. This chart helped organize the articles and identify information that compared the concussion intervention of subthreshold aerobic activity to the intervention of rest. The articles within the matrix were divided and categorized according to their level of evidence as determined by the "Hierarchy of Evidence for Intervention Studies" chart (Fineout-Overholt et al., 2010). Of the possible seven levels, four are represented: systematic reviews, randomized control trials, controlled trial without randomization, and case-control or cohort studies. Articles within each category are listed and summarized alphabetically according to the authors' last name. The matrix and analyzed information can be located in Appendix A.

Synthesis of Major Findings

Level 1 Evidence: Systematic reviews or meta-analyses are the type of evidence that make up level 1. Three articles reviewed fit into this category and are summarized below.

Lal, Kolaowsky-Hayner, Ghajar, and Balamane (2018) conducted a systematic review and meta-analysis with the intention of finding how physical exercise affects various outcomes in patients who have been diagnosed with a concussion. Databases used to find articles included MEDLINE, Scopus, Cochrane Central Register of Controlled Trials, PsycINFO, and

SPORTDiscus. Inclusion criteria consisted of any sex or age, patients who were diagnosed with an mTBI or concussion within the past three months, patients who completed an intervention such as stretching, biking, or treadmill activity, comparison to either physical rest or no physical exercise, and assessed outcomes with in the article such as but not limited to the Post-Concussion Symptom Scale (PCSS), Immediate Post-Concussion Assessment and Cognitive test (ImPACT), Balance Error Scoring System (BESS), neuropsychology tests, or duration of rest. A total of 14 articles were included in the study, and of those 14 studies, seven focused on adolescents, and one focused on children and adolescents. The remaining six studies included were conducted on adults. Randomized control trials, cohort studies, before and after studies, and a propensity score matching study were the types of studies used in the review.

The results from the included studies showed a significant decrease in PCSS scores when physical activity was added as an intervention in comparison to the control (rest or no physical activity) group (Lal et al., 2018). The number of days it took to return-to-play was not significantly different from the control. Another finding from this systematic review showed that the number of days it took the patient to return back to work was decreased. The physical activity group was able to return to work after an average of 17.7 days whereas the rest group averaged about 32.2 days. Furthermore, those who took the ImPACT and participated in physical activity saw better scores in reaction time, but the BESS test and neuropsychological parameters were not affected. The final result found “The Grading of Recommendations Assessment, Development and Evaluation (GRADE) scores were moderate for the PCSS, symptoms, ImPACT, BESS, and neuropsychological tests" (Lal et al., 2018, p. 743). Overall, this study shows that physical activity has a positive effect on patient symptoms and PCSS scores in those diagnosed with a sports-related concussion.

McLeod, Lewis, Whelihan, and Bacon (2017) conducted a study to review the use and effectiveness of rest as well as return-to-play protocols for sports-related concussions. Articles were found via 6 online databases: CINAHL, SPORTDiscus, Educational Resources Information Center, Ovid MEDLINE, and PubMed. To be included in the study, the articles had to be written in English, had to be original research, and had to evaluate rest or return-to-activity progression. "Narrative (clinical) reviews, editorials, critically appraised topics, commentaries, abstracts, animal research, studies of non-sport-related concussion, or original research that did not address the primary clinic questions of interest" were all excluded (McLeod et al., 2017, p. 263). After looking for articles that followed the specified inclusion and exclusion criteria, 40 articles were found. Nine articles addressed the use of rest, 10 articles studied the effectiveness of rest, 17 studies evaluated compliance with return-to-play guidelines, and 4 studies looked at return-to-activity outcomes. All studies were evaluated within their category group. Of the 40 included articles, five are addressed independently later in this Critical Review of the Literature. Authors of those studies include Gibson, Nigrovic, O'Brien, and Meehan (2013), Maerlender, Rieman, Lichtenstein, and Condiracci (2015), Moser, Glatts, and Schatz (2012), Moser, Schatz, Glenn, Kellias, and Ivrson (2015) and Thomas, Apps, Hoffman, McCrea, and Hammeke (2015) .

Results from McLeod et al. (2017) show that the use of rest is not being prescribed regularly to patients diagnosed with a SRC, or at least, rest is not being documented. In addition, confusion regarding how to prescribe rest on an individualized basis to patients is present. An initial period of cognitive and physical rest seems to help acute symptoms, but strict-rest appears to worsen symptoms and increase the duration of injury in comparison to those who participate in current standard care treatments. Findings from the articles discussing return-to play indicate return-to-play guidelines and assessment tools vary greatly between practitioners. This study also found more information is needed on the effectiveness of the return-to-play protocols. In conclusion, ambiguity is still persistent amongst healthcare providers on the use of cognitive rest, concussion-assessment tools, and return-to-play protocols. The most important finding correlating with the question addressed in chapter one is that rest is helpful right away post concussion, but the patient should be monitored as rest recommendations need to change as the patient's symptoms improve. Patient care must be personalized in concussion management and return-to-play at this time as so many questions about concussion rehabilitation persist (McLeod et al., 2017).

Schneider et al. (2017) completed a systematic review looking at the differences between rest and active treatments for individuals with a sport-related concussion. Specifically, they wanted to know the benefits of rest following a concussion and for how long someone should rest. The other main question they had asked about the effectiveness of active treatment for athletes with a SRC. They obtained all of their sources from OVID, EbscoHost, and Proquest databases. Their inclusion criteria was that the study had to be original research, had to have an SRC as the primary diagnosis, and had to evaluate the effects of rest and active treatment. Exclusion criteria eliminated all review articles. In total, 8224 citations were found using the databases, but only a total of 28 studies met all of the inclusion criteria. There were nine studies evaluating the effects of rest, and 19 studies evaluating active treatment. In total, 3218 patients between the ages of five and 53 were part of this study.

Schneider et al. (2017) found that cognitive and physical rest for the first 24 to 48 hours post-concussion is appropriate. However, after this time frame, the patient should begin to increase their activity level, but remain under their personal symptom exacerbation thresholds and avoid strenuous activity. Though these suggestions were made clear through this study, the researchers also recognized that the exact amount of rest is not yet known. They also made note that the quality of the articles were lacking as only five randomized control trials (RCT) were used out of the 28. Nonetheless, the findings still provide guidance that “closely monitored subsymptom threshold, submaximal exercise may be of benefit” (Schneider et al., 2017, p. 930).

Level 2 Evidence: Randomized control trials are the type of evidence that make up level two. 11 articles reviewed fit into this category and are summarized below.

Chrisman et al. (2019) studied youth between the ages of 12 and 18 years old who had persistent concussion symptoms and evaluated their responses to a minimal in-person subthreshold aerobic activity program or a stretching protocol. A total of 30 participants completed this study. Nineteen were randomized into the intervention (aerobic) group, and 11 were randomized into the control (stretching) group. In-person visits took place at the initial appointment and 6-weeks later when the program finished. Surveys were also taken at 3- and 6-month follow-up. All symptom reporting forms were completed online using the Health and Behavior Inventory. Accelerometry valuation was a main portion of this study too. This was evaluated for five to seven days at baseline, and again at six weeks post-intervention to objectively measure moderate to vigorous activity.

The intervention group participated in safe aerobic activity that did not go over 80% of the patient's target heart rate. This was tested and determined at the initial appointment via the Buffalo Concussion Treadmill Test (BCTT) (See Appendix C). In this group, participants were asked to complete aerobic activity daily for five to 10 minutes greater than their baseline moderate to vigorous activity accelerometry score. Each week, the aerobic activity would increase an additional five to 10 minutes as determined by the research assistant. The goal was to reach 60 minutes of exercise by the final week of treatment. If symptoms increased while exercising, the intensity was decreased by 10 percent. The participants were allowed to choose what activities they would like to do for this treatment. Treadmill, biking, stairs, and calisthenics were the most common methods chosen. The stretch group was given a program that would take about five to 10 minutes. They were asked to complete the program daily. This group was also contacted weekly to ensure they were tolerating the program well.

At the end of the study by Chrisman et al., patients who were in the subthreshold aerobic activity group saw a quicker decrease in symptoms compared to those in the stretch group. All improvements were maintained at six months. Results from this study also showed that the exercise continues to be a beneficial treatment for concussion injuries, and the exercise program can be followed correctly and adequately with minimal in-person contact with care providers.

Gladstone et al. (2019) investigated how 12 - 17-year olds diagnosed with a concussion responded to one of two programs: a full-body stretching program or a subthreshold aerobic training program. In addition, the patient's neurocognition was examined as well as their perception of quality of life. To be included in the study, the patient had to be within the acceptable age range, diagnosed with a concussion, symptomatic for a minimum of four weeks and maximum of 16 weeks, and symptomatic when activity increased. After the intake process, 30 of the 395 individuals evaluated were accepted into the study. Then, patients were asked to complete an aerobic bike test. They used a stationary bike and began at a level of 11 on the Borg rate of perceived exertion (RPE). The bike's resistance level was set at two, and the patient exercised at these settings for five minutes. After that, the patient was asked to increase their RPE by one level. This pattern continued for 30 minutes or until the patient reported symptoms. The patients reported back to the clinic a week later to be evaluated again. At this appointment, they were randomized into either the aerobic exercise group or stretching group. If placed in the aerobic exercise group, the patient completed the stationary bike test again to determine an appropriate, individualized home program. The prescribed exercise time was calculated by taking 80% of the time when the patient became symptomatic during the stationary bike test in the clinic. The aerobic exercise group was asked to complete their program five to six days a week and were given a stationary bike for their home. They returned to the clinic once a week over a six-week period to be re-evaluated and have their home program adjusted if needed. If the patient was randomized in the stretching group, they were also asked to complete their program five to six days of the week and check-in weekly with the clinic to either review their current program or receive new stretches.

Two evaluation forms were used. First, the NIH Toolbox Cognition Battery was used as it looks at the patient's cognitive, sensory, motor and emotional functions (Gladstone et al., 2019). Second, the pediatric Quality of Life Inventory (PedsQL) was used to assess the patient's physical, emotional, social, and school functioning. Results showed those in the subthreshold aerobic exercise group had better scores from the NIH Toolbox Cognition Battery than those in the stretching group when comparing pre-post scores. The PedsQL showed significant increases in both the subthreshold aerobic exercise group and the stretching group.

Overall, this study by Gladstone et al. indirectly stated that benefits are seen when subthreshold aerobic activity is prescribed to patients recovering from a concussion. Quality of life is increased in both the aerobic exercise group as well as the stretching group, but only the subthreshold aerobic exercise group showed significant improvement in neurocognition. Even though symptoms and duration of injury were not discussed, this study begins to answer the question of what is causing the quicker and better outcomes in patients participating in the subthreshold aerobic exercise programs. Exercise is known for increasing nerve growth factor in the brain and causes neurogenesis to occur in the hippocampus. This is significant as the hippocampus is responsible for learning and memory. Cerebral blood flow also increases with aerobic activity and "is thought to be the result of angiogenesis" which is "related to increased vascular endothelial growth factor" (Gladstone et al., 2019, p. 6). Again, this helps with fluid cognition and may be the specific reasoning why NIH Toolbox Cognition Battery measures were improved only in patients who completed subthreshold aerobic exercise.

Kurowski et al. (2017) conducted a six-week study looking at the possible benefits of subthreshold aerobic activity performed by concussed participants in comparison to a stretching program. Thirty participants were included in this study between the ages of 12 and 17. All participants were diagnosed with a mTBI and continue to experience symptoms anywhere from four weeks to 16 weeks post injury. At the first visit, patients were evaluated for eligibility and screened for neck concerns. Then, they completed an aerobic exertional test using a stationary bike. Patients were asked to begin biking at a pace that felt like a level 11 on the Borg rate of perceived exertion (RPE). Resistance was set to level two for five minutes. After those five minutes were completed, the patients were asked to increase their RPE by one level. This process was repeated until symptoms increased or the patient had been exercising for 30 minutes. At this time patients were excluded if they were unable to complete two minutes of activity or remained asymptomatic after 30 minutes. No treatment was given at this time. At the week one appointment, patients who remained eligible were entered into a run-in period. The run-in period allowed the researcher to see what symptom resolution may look like naturally without intervention. Patients were then randomized into either the aerobic activity group or stretching group. If placed in the aerobic group, the participants completed the aerobic exertional test on the stationary bike again, and the data from the test helped to form a personalized aerobic exercise program. Instructions to complete aerobic activity five or six days each week at 80% of the duration they experienced an increase in symptoms during the exertional test. Each week patients in this group would return and retest on the stationary bike, and new exercise levels were advised based on performance. Patients randomized into the full-body stretching group were also asked to complete their program five or six days each week. Upper and lower extremity stretches as well as trunk stretches were included. At their weekly appointments, the program was reviewed and every two weeks they would receive a new set of stretches. Both groups performed their programs for a total of six weeks. The data collected at week seven was considered the primary outcome of the study.

The Post Concussion Symptom Inventory (PCSI) was used to quantify symptoms and determine if the interventions were beneficial (Kurowski et al., 2017). Both the patients and their parents completed an inventory. Results showed that patient symptoms improved quicker in the subthreshold aerobic exercise group than in the stretching group with greatest improvements seen in the first four weeks of activity. However, parent PCSI scores did not show a significant difference between interventions. In conclusion, subthreshold aerobic activity is beneficial to use with adolescents who have prolonged symptoms of a concussion in comparison to a full-body stretching program.

Leddy et al. (2019) determined that subthreshold aerobic exercise is a beneficial treatment for adolescents diagnosed with a sports-related concussion. This intervention may speed the recovery and decrease the chances of having a prolonged recovery. In this RCT, subthreshold aerobic activity was compared to a stretching program during the acute phase of a concussion to determine the effectiveness of the treatments. To be eligible to partake in the study, participants needed to have sustained a sports-related concussion within the past 10 days and be between the ages of 13 and 18. Both males and females were included. In total, 103 individuals participated. 52 were in the aerobic exercise group while 51 were in the stretching group.

The aerobic group was asked to exercise aerobically for 20 minutes every day. Use of a stationary bike or treadmill was recommended but walking and jogging was acceptable if the participant did not have access to such exercise equipment. In addition, the athletes completed the BCTT at the first appointment to ensure they could safely exercise to at least 80% of their target heart rate. Clinicians would retest the BCTT weekly as long as the patient was still experiencing symptoms and advance the program as needed. The participants in this group were told to not stretch and to rest except for the 20 minutes of subthreshold aerobic activity they were being asked to complete.

The stretch group was given a program to follow every day that would not significantly increase their heart rate. They were also asked to complete their activity for 20 minutes daily and to rest. The athletes in the stretch group were given the same amount of attention as the exercise group and were also asked to complete the BCTT weekly as long as they remained symptomatic. Just as the aerobic group's program would advance weekly so would the stretch group's program.

Results from Leddy et al. (2019) showed that participating in aerobic exercise had a significant impact on the athlete's recovery and can be considered an effective treatment for concussions. Patients in the aerobic exercise group had a mean recovery of 13 days whereas the stretching group's recovery mean was at 17 days. Also, the aerobic group (n=2) had less participants with a delayed recovery in comparison to the stretching group (n=7). Symptom scoring was completed daily by the participants. The exercise group's symptoms improved quicker than the stretch group, but it was not considered significant. Overall, this study supported aerobic exercise as part of the recovery plan and is the first RCT that used subthreshold aerobic activity as a treatment within the first week of a concussion injury. The early initiation of treatment in this study is what makes it stand out amongst others currently available on this topic.

Leddy et al. (2018) studied a group of adolescents between the ages of 14 and 19. Both male and female high school athletes were welcome to participate as long as they had sustained a sports-related concussion within 10 days of starting the trial. A total of 54 individuals completed the study. The main goals were to see if exercise impacted the recovery of adolescents diagnosed with a sports-related concussion, and to evaluate the potential uses of the heart rate threshold of the BCTT to determine a predicted recovery time. At the initial visit, also known as visit number one, athletes were randomized into two groups: the BCTT group (n=27) or standard care group (n=27). The BCTT group received the exercise intervention, and the standard care group did not participate in any treadmill test as they were considered the control. At the first visit, all participants took the ImPACT test. Approximately 14 days later participants returned for the second visit and were retested. This time both groups were given the BCTT in addition to the ImPACT test. Between the first visit and second visit patients were responsible for recording their symptoms every evening via a program on the computer.

The protocol followed for the BCTT started at a zero percent incline and speed between 3.2 and 3.6 (Leddy et al., 2018). The exact speed used was determined by the patient's height. Every minute the incline was increased by one degree, but the speed would remain the same. The patient would complete the test until an increase in symptoms occurred or they fatigued. Each minute the athlete's heart rate, symptoms, and rating of perceived exertion (RPE) were recorded. After all testing was completed, the data was analyzed. The first goal of this study was assessed by looking at symptom scores in relation to recovery times when the BCTT was used. For analysis of the second goal, the average heart rate of the individuals randomized into the BCTT group was taken over the last minute of the BCTT during their first visit and their time to recovery was recorded too.

Results from the work of Leddy et al. (2018) showed the days to recovery were not significantly different between the BCTT group and standard care group. Further analysis on prolonged recovery verses typical recovery times were not significantly different between groups either. Both groups had decreased symptoms within the 14 days between the first visit and second visit, and those in the BCTT group did not see any increase in symptoms the day after the test. Also, prolonged recovery was associated with patients presenting with a lower heart rate at visit one. Conclusions that these individuals are likely to respond poorly to early exercise were made as well. Overall, conducting the BCTT does not cause any harm to the patient as early as the first week of being diagnosed with a sport-related concussion. The use of the BCTT is encouraged to help sport medicine clinicians prescribe appropriate subthreshold aerobic exercise as a treatment early after initial injury. Understanding the safety and effects for use of the BCTT after SRC allows future studies to be conducted on subthreshold aerobic exercise to see if it aids with recovery in ways that reduces symptoms quicker or speeds recovery (Leddy et al., 2018).

Maerlender et al. (2015) conducted a study with 28 college athletes who recently sustained a concussion. Participants were evaluated for a concussion as soon as possible by an athletic trainer. During the initial concussion evaluation, the athlete was asked if they would be interested in participating in a research study. If consent was obtained, the athlete was assigned to either the standard care group or the physical exertion group. In total, 12 females and three males were in the standard care group, and eight females and five males were in the physical exertion group. Then, the athletes were told to meet with the designated research AT daily. Primarily, the daily meetings were scheduled to check on the patient's current status and activity level. Tests that were used to monitor the athlete's recovery include a demographic questionnaire, ImPACT, the Borg CR10 RPE scale, the post-ride symptom change rating, and accelerometer graphs.

Athletes in the physical exertion group used a stationary bike to complete their exercise program at a RPE level within the range of zero to six (Maerlender et al., 2015). The particular RPE scale used goes to a maximum level of 10, so exercising at levels zero to six would be considered mild to moderate activity. The goal for the athlete was to reach 20 minutes of biking, but if their symptoms became uncomfortable, they were asked to stop. After completing the activity, the participants would document the highest RPE scale level achieved during their session as well as any changes in symptoms. This protocol was completed daily until no symptoms were experienced post exertion. Patients in the standard care group were told to avoid any activities beyond those needed for school. The use of accelerometer data was the only method used to verify the athlete's activity level throughout the study.

Results showed no significant difference between groups in the median number of days to recovery. Those involved in the physical exertion group noted more symptom changes over having no changes after each session. For example, after completing a mild level ride, an average of 1.8 symptoms would increase. Researchers saw that vigorous activity was associated with an increased recovery time; however, mild symptom increases did not interfere with recovery. In conclusion, this study showed physical exertion following a concussion can begin shortly after injury, but it may not be more beneficial than standard care protocols (Maerlender et al., 2015).

Micay et al. (2018) looked at a population of 15 male adolescents who were diagnosed with a sport-related concussion by a physician to determine if subthreshold aerobic activity was feasible and if the intervention was effective. Effectiveness was defined as symptom reduction and time to return-to-play. To be included in this study, the participants had to remain symptomatic five days after the injury date and be between the ages of 14 and 18. Once included in the study, patients were randomized into either the exercise group or usual care group. A total of eight patients were in the aerobic exercise group and seven patients were in the usual care group. The aerobic exercise group started their intervention six days post injury which included eight sessions using a stationary bike. Increases of the intensity and duration on the bike occurred throughout the sessions. During the first session, the patient biked for 10 minutes at 50% of their maximal heart rate. The second session increased to 20 minutes in duration, but the heart rate goal remained the same as the first week. All following sessions increased activity time by 20 minutes. The patient's heart rate was also increased by five percent each session after the second week, but they could not exceed 70% of their maximum heart rate at any given time. The patients in the aerobic exercise group were instructed to complete this activity two days consecutively and then take a rest day. This schedule was adhered to for a total of 11 days. The PCSS was used to gather symptoms scores before and after each exercise session. The usual care group rested until told otherwise by a physician. When activity was advised to participants in the usual care group, they were not supervised. All participants, in both groups, were evaluated once a week for four weeks.

Results from the study by Micay et al. indicated that aerobic activity was safe to administer and does not cause symptom exasperation. Effectiveness of aerobic activity was not significantly different than the usual care group in terms of return-to-play. However, correlation between symptom severity and time to medical clearance was apparent. The more initial symptoms a patient presented with, the longer recovery and time until they were back to their preinjury performance levels. Furthermore, symptom severity improved quicker in patients who participated in the aerobic exercise group than the usual care group. Significant reduction in symptoms occurred in the aerobic exercise group between weeks one and three, but the usual care group did not have significant reduction in symptoms until week four. This finding validates the use of subthreshold aerobic exercise as a treatment for a SRC in the postacute phase (Micay et al., 2018).

Mychasiuk, Hehar, Ma, Candy, and Esser (2016) studied rats to discover how voluntary exercise affects concussion recovery in terms of symptom resolution and return-to-exercise. The rats were randomly selected to be given a mTBI through a lateral impact device or sham injury. The rats were all anesthetized for the lateral impact which caused a 180 degree horizontal rotation to occur, simulating a concussion. Then, subjects were placed into one of five groups varying in running wheel conditions. Group one were rats who received a mTBI and no exercise. The rats were kept in their cages with three other subjects, but did not have access to a running wheel. In total this group was made up of 11 males and nine females. Group two consisted of rats who sustained a mTBI and were allowed to immediately return to their running wheel. A total of eight males and eight females were in this group. Group three consisted of rats who sustained a mTBI but were delayed three days before allowed access to their running wheels. Nine males and eight females were in this group. Group four was similar to group two; however, the rats were not given a running wheel until seven days post injury. This group had eight males and eight females. Group five included the rats who were not allowed socialization and play. These five groups were compared to the control groups. This first control group consisted of rats (20 males and 18 females) who were allowed to exercise, and the second control group (8 males and 9 females) consisted of rats who were not allowed to exercise. Specific outcomes evaluated in this study included topics surrounding exercise, behavior, and socialization post mTBI. Telomere length and gene expression changes were also evaluated in the prefrontal cortex and hippocampus.

Mychasiuk et al. (2016) concluded that if exercise was part of the treatment plan within the first three days post injury, significant motor and cognitive functioning was positively affected. Also, rats who were in the no play and no exercise group did not recover well. Rats in this group performed at a similar level as the animals who sustained a mTBI and did not exercise. This was noted as a significant finding because the lack of socialization and activity mimicked what happens when a patient is recommended strict rest post concussion. Furthermore, gene expression and telomere length measurements showed that exercise helped the brain to recover quicker in both the hippocampus and prefrontal cortex. All these findings work together to prove that exercise is a beneficial treatment for pediatric patients diagnosed with a concussion.

Sufrinko et al. (2017) conducted a secondary analysis of a randomized control trial looking at whether the response to concussion treatments of activity or rest differs if the patient had signs of a concussion or only symptoms of a concussion. Signs were defined as external findings such as loss of consciousness or amnesia. Symptoms are defined as the patient's subjective perception of their condition such as headache, dizziness, or fogginess. All 93 participants included in this study were between the ages of 11 and 18 years old and presented to the emergency department within 24 hours of injury.

Depending on the participants' history they were either placed in the signs or symptoms only group. After that, patients were randomized into the rest group or standard care group. The standard care group was allowed to be prescribed exercise as seen fit by the physician. The signs group had 17 participants in the standard care group, and 19 were in the rest group. The symptoms groups had 29 participants in the standard care group and 29 participants in the rest group. All participants completed a symptom and activity journal for 10 days. They also attended follow up appointments.

The conclusion of this study by Sufrinko et al. (2017) found a distinct difference in how patients with signs or only symptoms of a concussion respond to strict rest. Patients in the signs group benefited from being part of the rest only group as it improved their verbal memory scores, but patients with only symptoms did not see the same improvement. Also, patients in the rest only group were made more symptomatic within the first 10 days post-concussion. Sufrinko et al. suggests this may be because patients who are more symptomatic present to the emergency department with more fear and anxiousness about symptoms. Then, when the patient is told to rest, they may become emotionally distressed causing secondary symptoms to develop too. Rest seems to be helpful for individuals with signs of a concussion, but standard care is better for patients presenting with only symptoms of a concussion. This study demonstrates that individualized, personal care is necessary for patients diagnosed with a concussion (Sufrinko et al., 2017).

Teel et al. (2018) studied 40 individuals aged 18 through 30 to see the effects of aerobic exercise on concussion outcomes in a healthy population. To be included, participants needed to fit the age requirements as well as exercise three or more days a week. Once the individual was determined eligible for the study, they were randomized into two groups. The intervention group (aerobic activity) and non-intervention group. No matter the group the patient was assigned to, everyone completed concussion metrics and an exertional aerobic test via a stationary bike. This was done two times approximately 14 days apart. Between the two testing dates the intervention group completed six sessions where they would exercise for 30 minutes. The intensity was determined by the patients maximal oxygen consumption. For the first session, the individual would exercise at 60% of this maximum. By the last session, patients were exercising at 80% of their maximal oxygen consumption. Oxygen level checks occurred during activity at five, 15, and 25 minutes. The non-intervention group was also known as the non-training group, and they did not participate in any specific protocol.

Concussion metrics evaluated included symptoms, cognition, balance and vision (Teel et al., 2018). A variety of tools were used to determine the outcomes of the two groups. The CNS vital signs test assessed areas such as attention span, problem solving, and reaction time. The Standardized Assessment of Concussion evaluated orientation, immediate and delayed memory, and concentration. The BESS tested the patient's balance, and the Graded Symptom Checklist was used to report and rate severity of symptoms. The final test used to evaluate concussion metric was the Vestibular/ Ocular Motor Screening (VOMS) which guides the patient through a variety of visual tasks. The patient was also asked to report any dizziness, headache, nausea, or fogginess before or immediately after this particular test.

The outcomes from these measurements showed that the intervention groups symptoms improved between sessions. In addition, "Cognitive flexibility, executive functioning, reasoning, and total symptoms score outcomes were better, but composite memory, verbal memory, and near-point convergence distance scores were worse at the second session" (Teel et al., 2018, p. 1156). Though considered worse, both the intervention group and nonintervention group had predominantly a small-sized effect. The only medium-sized effect was the intervention group in regard to symptom scores. Overall, the intervention of aerobic activity did not have many effects on concussion assessments with a healthy population. This means concussion outcome tests can continue to be used without making adjustments to scores when an aerobic intervention is used and return-to-play decisions can be made as current recommendations suggest.

Thomas et al. (2015) conducted a study on 88 patients diagnosed with a concussion in the emergency room. He looked specifically at the intervention of strict rest and compared it to current standards for treatment. The goal of the study was to determine if strict rest improved recovery and outcomes for those with concussions. All included participants sustained a concussion within the past 24 hours, presented to the emergency department, and were between the ages of 11 and 22. Once the patients consented to the study, they were asked to complete a balance test called the BESS test as well as a neurocognition test (ImPACT). Then, participants were randomized into one of two groups. Either the intervention group (n=45) or standard care group (n=43). The intervention group consisted of strict rest which meant five days of only rest. School and work were not permitted for members in this group. After the five days, the patients would begin a return-to-activity program. The standard care group or the control group were instructed to rest for the first one to two days but could begin a program to return-to-activity after that. Both groups were asked to keep a journal and record their physical activity, mental activity, and symptom severity. Symptoms were rated according to the PCSS. Follow-up appointments were completed at day three as well as day 10. Patients would complete the balance, neurocognition, and neuropsychiatric assessments at the follow-up appointments. Data was evaluated by using linear mixed-model analyses and sample size calculations.

The primary result from this study concluded that individuals who were part of the strict rest group reported more symptoms on a daily basis and a slower recovery. This finding indicates that strict rest initially after a concussion does not assist the recovery process and may have caused symptoms to increase. Additionally, balance and neurocognition test scores were not significantly different than the control group. Using the standard care approach of rest is still considered the better treatment option and is recommended for pediatric patients to follow after being diagnosed with a concussion (Thomas et al., 2015).

Level 3 Evidence: Controlled trials without randomization are the type of evidence that make up level 3. Three articles reviewed fit into this category and are summarized below.

Moser et al. (2012) studied the treatment outcomes of cognitive and physical rest for 49 high school and collegiate athletes who sustained a concussion. All participants were between the ages of 14 and 23. Also, 67% of the population were male and 33% were female. After patients were diagnosed with a concussion, they were prescribed at least one week of cognitive and physical rest as treatment by a physician at the Sports Concussion Center of New Jersey (SCCNJ). Patients were divided into groups based on their date of injury and when they presented to the SSCNJ. Group 1 (n = 14) consisted of patients who presented to the clinic within one to seven days. Group 2 (n = 22) consisted of patients who presented to the clinic within eight to 30 days, and group three (n = 13) consisted of patients who presented to the clinic within more than 31 days post-injury.

Protocol followed for the intake process of patients included completion of paperwork, medical history exam, ImPACT post-concussion testing, an education session on ImPACT results and prescribed rest treatment, and instructions to follow-up no sooner than a week. Patients continued to attend follow-up appointments until ImPACT scores normalized, they were asymptomatic with and without physical exertion, and were cleared for pre-injury activities. For symptom scoring the Concussion Symptom Scale was used. Rest in this study was instructed as no school, homework, travel, trips outside the house, driving, visits with friends outside the house, computer, texting, video games, reading, chores, and no physical exercise. The patients were not allowed to participate in any sporting activities and almost all took off one week of school. At the second appointment, patients were either instructed to continue rest or start returning to school. Accomodations for school were given and patients were still instructed to not participate in physical activity. However, if the patient felt they were improving significantly, they were told to call the SCCNJ to see if adding some more activity would be reasonable prior to their next appointment.

At the end of the study, results showed significant improvements in ImPACT scores as well as symptom scores (Moser et al., 2012). No matter the group the patient was categorized into, no significant difference was seen in symptom scores. Another group of 28 patients received an extra week of rest. These patients had similar results to the other groups, but they did score better in verbal memory, processing speed, and reaction time sections of the ImPACT test. The improvements in all groups show cognitive and physical rest may be a useful tool for concussion treatment whether the athlete is in an acute phase or prolonged phase.

Moser et al. (2015) looked at adolescent athletes who had been diagnosed with a concussion and their response to 1 week of prescribed rest. The total population of this study was 13 athletes between the ages of 12 and 23 years old, and all were experiencing a prolonged recovery. Also, 77% of the participants reported a diagnosis of ADHD, learning disability, or two prior concussions. Inclusion criteria involved not taking part in rest prior to the study, taking the ImPACT test within one month of injury, taking the ImPACT test again at the initial appointment before rest, following instructions for rest treatment, and completing another ImPACT test at the follow-up appointment. "The present study replicates and extends the study by Moser et al. [2012], while attempting to control for possible spontaneous recovery" (Moser et al., 2015, p. 59).

Patients completed the ImPACT test prior to coming to the clinic and took the test again at the clinic. In addition, education on how to follow the required rest was reviewed by giving the patient a list of activities to avoid which included physical exercise, chores, attending school, homework, traveling, trips outside the home, computer use, and other similar activities. Patients were encouraged to listen to relaxing music, listen to audiobooks, fold laundry, take slow walks, sleep, meditate, or take a bath.

ANOVA tests were used in the study by Moser et al. (2015) to show significant differences, and it found that rest does improve ImPACT scores and total symptoms scores. Post hoc analysis was also completed. It showed no difference in symptoms or ImPACT scores between the pre-clinic and first appointment assessments, but significant differences in symptoms or ImPACT scores were seen between the time rest was prescribed to the follow-up appointment. In all, symptoms were improved in 54% of patients, but that percentage increases to 87% of patients if narrowing the population to only those who had increased concussion symptoms before starting the rest treatment. After completing the rest treatment, improvement was determined if ImPACT scores were better in two or more cognitive areas or symptoms scores were decreased. Therefore, a total of eight or 61.5 percent of participants benefited from rest as a treatment for prolonged concussion recovery. Overall, this study concluded that using education, reassurance, and one week of rest as concussion treatment works to reduce symptoms and improve cognitive function in adolescents.

Willer et al. (2019) set out to compare aerobic exercise, placebo-like stretching, and rest interventions in adolescents who were diagnosed with a sports-related concussion. He also looked at differences among females and males. To be included in this study, athletes had to be at least 13 years old and no older than 18 years old. They also needed to present within 10 days of SRC. Once determined eligible to participate in the study, the patients were placed into one of three groups. A total of 48 athletes were in the rest group, 52 athletes were in the exercise group, and 51 athletes were in the placebo-like stretching group.

All groups were required to submit their symptom scores using the Post Concussion Symptom Score (PCSS) tool every evening via a computer program between the hours of 7pm and 10pm (Willer et al., 2019). The exercise group were given a subthreshold aerobic exercise program based on their heart rate achieved during the BCTT. Specifically, 80 percent of the patient's heart rate at the end of the BCTT was used for their individualized subthreshold aerobic exercise program. The activity the athletes were required to complete daily consisted of 20 minutes on a stationary bike or treadmill at the target heart rate. A five-minute warm-up and cool-down was also incorporated. If symptoms worsened prior to the 20 minutes, the athlete was asked to stop. For accuracy, all participants in this group were given a watch that displayed the individual's current heart rate. Each week, patients in this group would return for an appointment to take the BCTT again and determine a new subthreshold aerobic activity heart rate goal. Participants in the stretching group were given a packet with breathing exercises and whole-body stretches. Every week the stretches were a bit more difficult, but the program was designed to not raise the patient's heart rate. The athletes in this group were also required to complete their program for 20 minutes every day and were given a watch with a heart rate feature to make sure their heart rate did not increase significantly over their resting heart rate during stretching. They also completed the BCTT every week. Finally, the rest group was told rest is needed for their brain to heal. They were instructed to not participate in sports, gym class, or any other activity that increased their heart rate. They were also told to avoid watching television or using their phones. This is unique to the rest group as the other groups were not advised in this way. Athletes in the rest group were still required to come into the clinic every week to complete the BCTT.

Results from this study showed the rest group recovered in approximately 16 days which was significantly delayed (P=.020) from the exercise group whose median recovery was at 13 days. The placebo group also was significantly delayed in recovery at 17 days. The exercise group only had four percent of its population experience a delayed recovery whereas the placebo group had 14 percent and the rest group had 13 percent. The comparison between males and females did not result in any significant differences, but the females did report more symptoms if in the rest group. These findings showed that the rest group and placebo-like stretching group had similar outcomes in days to recovery and symptom reporting. Subsymptom threshold aerobic exercise prescribed within the first week of a SRC was the most effective intervention out of the three and resulted in quicker recovery from a SRC.

Level 4 Evidence: Case-control or cohort studies are the type of evidence that make up level 4. Eight articles reviewed fit into this category and are summarized below.

Cordingley et al. (2016) conducted a study that looked "to evaluate the safety, tolerability, and clinical use of graded aerobic treadmill testing" and "to evaluate the clinical outcomes of treatment with a submaximal aerobic exercise program" (Cordingley et al., 2016, p. 693). One hundred six patients were included in the study. They were between the ages of 11 and 19 and were diagnosed with an acute sports-related concussion or were experiencing a prolonged recovery due to a SRC. During the initial appointment, patients filled out information regarding demographics, medical history, previous concussions, and family history. They also filled out the PCSS. When necessary, parents helped their child report this information. A neurosurgeon completed the clinical history and physical exam.

Moving forward with the study, patients were asked to complete a graded aerobic treadmill test. Specifically, the BCTT was used “to assess physiological recovery, classify post-concussion syndrome subtype, and reassess patients following treatment” (Cordingley, et al., 2016, p. 693). The participants were then categorized into four groups. Those groups were physiologically recovered, physiological post-concussion disorder (PCD), vestibulo-ocular PCD, and cervicogenic PCD. Physiological PCD means the patient is still experiencing symptoms whereas vestibulo-ocular PCD meant the patient did not have symptoms during the treadmill test but still qualified for the study based on vestibulo-ocular dysfunction. Cervicogenic PCD means that the patient did not experience symptoms during the treadmill test either but qualified to remain in the study due to a potential neck soft tissue injury. Patients part of the physiological PCD were given a specific protocol to follow in regard to their at-home exercises. They were asked to complete a five-minute warm up, 20-minute aerobic exercise at 80% of their maximum heart rate achieved at the clinic, and a five-minute cool down five days a week. Follow up occurred every two to four weeks to advance or change the program.

The results of the study by Cordingley et al. showed physiological recovery in 63 of the 65 patients tested. This test also identified 58 patients who could be classified with physiological PCD and one patient as cervicogenic PCD. Furthermore, 41 patients completed all the follow up steps in the physiological PCD group and completed the submaximal aerobic exercise protocol.

In total, 37 patients out of the 41 improved and 33 returned to sports. Overall, graded aerobic testing was proven to be safe, tolerable, and clinically valuable for pediatric patients. The protocol used can be beneficial for both diagnostic and management purposes (Cordingley et al., 2016).

Dobney et al. (2018) conducted a study to estimate the time frame when patients with a concussion experience the greatest decrease in symptoms after being introduced to aerobic rehabilitation. Participants reported to Montreal Children's hospital where they were evaluated, diagnosed, and treated for a concussion. If the patient was not improving after two weeks post injury, they were referred for active rehabilitation which has been an ongoing program through this hospital. In all, 677 patients participated in this study and 54% were female. Their average age was around 14 years old.

Patients who were enrolled in the study reported their symptoms at three different appointments: the initial appointment when they were entered into the active rehabilitation concussion program, their first appointment at physiotherapy, and at their follow-up physiotherapy appointment. The tool used to gather symptoms scores was the Post-Concussion Scale- Revised (PCS). Symptoms were always recorded prior to activity. Activity rehabilitation protocol included aerobic activity, coordination/skill practice, visualization, education, and motivation. For aerobic activity, patients were to exercise on a stationary bike or treadmill at 60% of their maximum heart rate. This activity was completed for 15 minutes daily. If symptoms worsened during this time, the patient stopped exercising. Also, if the patient needed to stop prior to 15 minutes, the time stopped at became the new goal for their home program. Coordination and skill were individualized based on sport specific activities such as shooting or stick handling. This was done for a maximum of 10 minutes. Heart rate was monitored while the patient completed their aerobic activity as well as during sport specific skill work. Then, the participant would complete five to 10 minutes of visualization. Lastly, education was given at each clinic visit (Dobney et al., 2018). Topics such as expected recovery, symptom progression, coping with a concussion injury, and return-to-sport/school were addressed. Patients were instructed to continue the program at home and record what activities they did each day as well as their symptoms.

On average, patients would begin active rehabilitation 45 days post-concussion (Dobney et al., 2018). If categorized in the group where activity was started less than two weeks' post-concussion, the patients started around day nine. Those in the six weeks or more groups started activity 87 days post-concussion on average. From the initial physiotherapy appointment to the follow-up appointment, all patients saw a decrease in symptoms. However, the patients who started activity within two or three weeks saw more significant improvements at the follow-up appointment than those who started after six weeks. Also, the participants who started active rehabilitation at two weeks reported less symptom severity than the patients who started activity at less than two weeks, four weeks, and five weeks post injury. Patients who started activity at less than two weeks or more than six weeks post concussion had similar results in symptom scores. In conclusion, this study shows that active rehabilitation is beneficial as a treatment for concussion in children and adolescents who are slow to recover. All groups saw improvements, and they did not differ based on the timing active rehabilitation was initiated.

Gibson et al. (2013) studied cognitive rest and its effects on symptoms of a sports-related concussion. In order to be included in this study, the athlete had to sustain a concussion due to sport or a similar mechanism and be symptom-free by the end of the study. A total of 184 patients fit this criteria and therefore, were included. All participants were between the ages of eight and 26. After diagnosis, patients completed the PCSS, BESS test, and a neurocognitive test. They continued to follow-up at the clinic for check-in and retesting of the BESS test and computerized neurocognitive test. The point in which patients would return for an appointment was not consistent amongst all participants. All patients were also asked to complete PCSS symptom inventory on a daily basis throughout their recovery as it was the primary outcome being assessed.

Data gathered for analysis included demographics, concussion history, PCSS scores and treatment plans (Gibson et al., 2013). Specific attention was given to find if cognitive rest was recommended to the patient. The patient's medical record needed to state that rest was recommended rather than self-reported. A total of 135 athletes had completed medical records and were analysed. The results looked at the symptoms of patients who recovered less than 30 days and those who took over 30 days to recover. It also looked at the relationship between cognitive rest and symptom resolution. Overall, 85 athletes were recommended cognitive rest, and 58% of the athletes recommended for rest were under the age of 15. 79 of the athletes in the rest group also experienced a prolonged recovery. The mean time it took to recover from a concussion in athletes who were prescribed rest was about 57 days compared to 29 days for those who were not prescribed rest. However, only “the initial PCSS score was associated with the duration of concussion symptoms” (Gibson et al., 2013, p. 840). The recommendation for cognitive rest was not related to the time it took for symptom resolution. Overall, prolonged cognitive rest should be advised with caution as the evidence for its effects remains limited.

Grool et al. (2016) studied patients who had been diagnosed with a concussion to determine if physical activity participation within seven days post injury has an impact on the occurrence of persistent postconcussive symptoms (PPCS). Individuals who reported to the emergency department for a concussion, were between the ages of five and 17, and did not have any of the exclusion criteria were allowed to be part of this study. In total, 3063 patients were enrolled, but 2413 patients completed all necessary requirements 9. At the initial appointment, participants gave information regarding demographics and prior concussion injuries. Parents were allowed to help if needed. Then, injury characteristics were recorded using the Acute Concussion Evaluation inventory, and symptoms were recorded using the Post-Concussion Symptom Inventory (PCSI). The SCAT-3 was administered to assess balance, cognition, and physical signs as well. Follow-up appointments occurred via online or phone at seven days and 28 days post enrollment. Parents documented symptoms for their children if they were between the ages of five and seven. All other participants self-reported their symptoms. In addition to reporting symptoms, patients reported any physical activity they were participating in. This was noted by selection of a category that best fit the patient. Categories included no activity, light aerobic exercise, moderate exercise, and full exercise. Descriptions of each category were provided.

The main outcome evaluated was the occurrence of PPCS which was defined as at least three symptoms that were new or worsened over the 28 days of the study (Grool et al., 2016). A total of 733 patients developed PPCS. Results showed 1677 individuals participated in the early physical activity and 736 individuals had no physical activity. Those categorized in the early physical activity group had a lower chance of PPCS than those who did not participate in physical activity. Also, patients who were symptomatic at day seven were less likely to have PPCS if participating in light aerobic activity, moderate activity, or full-contact activity than those who were not doing any physical activity. Statistical analysis using a propensity match score helped to evaluate the effectiveness of physical activity as a concussion treatment, and concluded, based on the symptoms reported on day 28, that early physical activity is beneficial. The PPCS scores taken on day 28 found 28.7 percent of patients who participated in early physical activity reported post-concussive symptoms. This differs from the patients who partook in conservative rest as 40.1 percent in that group were still reporting symptoms at that time. This significant difference indicates that taking part in physical activity within one week of a concussion injury may help with symptom resolution and decrease the likelihood of PPCS in children and adolescents.

Howell et al. (2020) conducted a study to identify any relationships between participation in exercise post-concussion and symptom severity, postural control, and time to symptom-resolution. The population consisted of 72 D1 collegiate athletes who were all 18 years old or older. Anyone who had a lower extremity injury affecting gait, a current psychiatric condition, a concussion diagnosed within the past six months, or were delayed in getting paperwork completed were excluded from the study. All participants were asked to complete the PCSS within 48 hours of their injury. Then, they completed the PCSS again along with a dual-task and balance assessment at the follow-up appointment. The follow-up appointment took place anywhere between two and seven days post-concussion. No randomization occurred in this study, but participants were divided into groups. The first group consisted of athletes who partook in exercise between their initial injury and the follow-up appointment (n=13). The second group consisted of athletes who did not participate in any exercise between their injury and follow-up appointment (n=59). The decision to allow patients to exercise in the time frame before the follow-up appointment was made by a medical provider and confirmed by the team physician.

Those in the exercise group initially rested but shortly after sustaining their concussion, they began exercising under the supervision of a clinician within. The athletes could either exercise by biking on a stationary bike or by lightly jogging on a treadmill for 10 to 15 minutes as long as their symptoms did not exasperate. If symptoms did increase during activity, the athlete was asked to stop. The athlete could try the activity again the next day as long as their symptoms had returned to the level where it was the previous day prior to exercising. Intensity, duration, and frequency of exercise was not documented. At the follow-up appointment, all athletes, in both groups, were asked to complete a single and dual task gait assessment. The single task was to walk normally along a path whereas the dual task required the athlete to walk and complete a cognitive test at the same time. Inertial measurement sensors were worn by the patient during this test, but the main measurement used in the evaluation process was walking speed. In addition, the modified BESS test was completed which meant the athlete's balance was only conducted on a hard surface.

Results showed no significant differences between groups and the duration of time to symptom resolution. Symptom scores were similar at the initial concussion evaluation. However, when the time between initial injury and when the assessment was taken was calculated into the equation, the findings showed that the exercise group reported less symptoms than the no exercise group at both the initial evaluation and follow-up appointment. Also, the exercise group performed better at the dual task then the no exercise group. The single task speed, cognitive accuracy, and modified BESS test were not significantly different between groups. These findings prove that athletes who participated in aerobic exercise following a concussion did not experience detrimental results. Rather those in the exercise group experienced lower symptom scores. Therefore, completing exercise within the first week of sustaining a concussion is safe and acceptable to recommend (Howell et al., 2020).

Howell et al. (2016) looked at the relationship physical activity has on the duration of symptoms following a sports-related concussion. Duration of symptoms was defined as the days between the date of injury and the last day the patient experienced symptoms. Included in his study were 364 patients between the ages of eight and 27 years old who reported to a speciality concussion clinic. Of the 364 participants, 222 were male. Also, all participants had to be diagnosed with a concussion within 21 days of injury. All concussions were either sports related or had a similar mechanism of injury to a SRC. If the patient fit all of the inclusion criteria and consented to be part of the study, they completed forms asking about their demographics and other clinical information. Once those were completed, they were instructed to complete a symptom inventory called the PCSS. For younger patients, parents were allowed to help complete these forms.

Physical activity was evaluated at the first visit as well as at follow-up appointments (Howell et al., 2016). At the first visit, participants were asked if they had been exercising since their injury. This was asked to see how physical activity can affect recovery from a concussion in acute situations. At the follow-up appointments, patients were asked about their physical activity as well as their cognitive activity. To objectify what the patient was reporting, scales were used based off of the return-to-play protocol developed at the 4th concussion conference in Zurich. All data was self-reported by the patient.

Results showed the mean PCSS score at the first visit was about 34, and the total mean symptom duration was approximately 49 days. If the patient presented with a high PCSS score or were female, they were more likely to have a longer duration of symptoms, but the level of physical activity after the sustained concussion was not associated with a longer recovery. Furthermore, patients between the ages of 13 and 18 years saw decreased symptoms duration when partaking in higher physical activity levels. This outcome was not found in the younger group or older age groups indicating physical activity treatment may affect symptoms differently based on the patient's stage of development. Overall, this study found that "physical activity may not be universally detrimental to the recovery of concussion symptoms" (Howell et al., 2016, p. 1045).

Lawrence, Richards, Comper and Hutchison (2018) were determined to find if aerobic activity after sustaining a concussion would help with a quicker return-to-play and return-to-school. Data of 253 concussions were collected from a sports medicine clinic between October 2016 and December 2017. To be included in this study, the concussion injury had to be sports-related and presented to the clinic within 14 days. All ages, sports, and skill levels were acceptable. The study focused on the number of days between the injury date and when aerobic activity was introduced. The activity could be self-initiated or physician prescribed. Also, patient demographics, concussion history, and conditions common with prolonged recovery were collected.

Results showed through statistical analysis that the sooner patients initiated aerobic activity the sooner they were able to return-to-play and return-to-school (Lawrence et al., 2018). Each day that aerobic activity was delayed, the greater the patient was likely to experience a longer recovery. “Initiating aerobic exercise at three and seven days following injury was associated with a respective 36.5% and 73.2% reduced probability of faster full return to sport compared to within one day; and a respective 45.9% and 83.1% reduced probability of faster full return to school/work” (Lawrence et al., 2018, p. 1). Also, previous concussion history, the severity of symptoms, and loss of consciousness all negatively impacted recovery duration. In conclusion, athletes who are diagnosed with a SRC and participate in early aerobic activity are associated with a quicker recovery which proves starting aerobic activity within one week of injury is safe and beneficial.

Silverberg and Otamendi (2019) conducted a study with 146 participants to evaluate what physicians are advising for concussion treatment when it comes to rest or activity and how the patient responds to the recommendation. He also looked at how clinical outcomes were affected based on the advice given and if certain patient characteristics changed the advice given. Participants from two separate clinics in Canada completed the Rivermead Post-Concussion Symptom Questionnaire, PHQ-9, GAD-7, and a questionnaire specially designed for this study. In the questionnaire for this specific study, information about the patient, their injury as well as their recovery was gathered. It also inquired if they were recommended by a health care practitioner to rest for more than post-concussion. The participants also documented whether they were fully returned to work or school, partially returned to work or school, on leave, or if none of the options fit their situation. Participants in this study were between the ages of 18 and

60 years old, were diagnosed with a concussion within the past three months, spoke English, and could access primary health care.

Results from the study by Silverberg and Otamendi showed 82.9% of the participants were advised to rest for more than two days. The recommendation was not based on patient demographics such as gender, race, or previous concussion history. Furthermore, participants who were in the rest group took longer to return to work as 64.5% of patients in the rest group were still on leave from work or school at the time of intake whereas only 40% of patients in the control group were still on leave at that time. The rest group was also behind the control group in the number of patients who had partially returned for fully returned to work or school by the intake appointment. Evaluation of concussion symptoms, anxiety, and depression did not show significant differences. Recommendations following the findings of this study suggest to focus more on individualizing patient care and discontinuing the general recommendation of rest for longer than two days after sustaining a concussion to match practice with current literature and guidelines (Silverberg & Otamendi, 2019).

Critique of Strengths and Weaknesses

Throughout the appraisal of the above 25 articles, many strengths and weaknesses were identified. One important strength was all articles, except for one, were of good or excellent quality. Another strength was the uniformity of tests used to identify the outcomes of the studies. For example, 11 of the articles used the PCSS score to evaluate patient symptoms. In addition, the research findings were consistent as 23 of the 25 studies either recommended subthreshold activity, demonstrated that it was safe, found participating in an aerobic intervention was not more detrimental than rest, or concluded rest to be harmful in concussion rehabilitation. Also, all research was published within the past 8 years.

Weaknesses of this study were present too. Small population sizes were a common finding, and the majority of the studies were under 200 participants. Only 4 articles had greater population sizes including Lawrence et al. (2018) at 253, Howell et al. (2016) at 364, Dobney et al. (2018) at 677, and Grool et al. (2016) at 2413. More studies with larger sample sizes would help findings be of greater significance. Another weakness was the low number of systematic reviews and its poor integration of RCTs. Both quantity as well as quality of RCTs were minimal within the systematic reviews. Nonetheless, due to the preliminary nature of this topic, these weaknesses were understandable.

Summary

Twenty-five research articles were critically reviewed to determine whether subthreshold aerobic activity or rest provided a more effective treatment for symptom reduction and time to return-to-play in patients who were diagnosed with a concussion. All articles were categorized into level I, II, II, or IV according to the “Hierarchy of Evidence for Intervention Studies” chart (Fineout-Overholt et al., 2010). The articles were assessed for quality and represented levels of fair, good, and excellent according to the PEDro scale, CASP questionnaire and series of four questions (The George Institute for Global Health, n.d.; Raab & Craig, 2016). Twenty-three of the 25 studies either recommended subthreshold activity, demonstrated that it was safe, found participating in an aerobic intervention was not more detrimental than rest, or concluded rest to be harmful in concussion rehabilitation. Three studies recommended rest as a quality intervention for concussion treatment, but none of those studies compared rest to subthreshold aerobic activity. Strict rest for prolonged periods of time was not recommended by any article. One article is represented in both categories due to split results depending on the population. Though the total article count may appear to be 26, only 25 articles were reviewed.

Chapter IV: Discussion, Implications, and Conclusions

The purpose of this review is to determine whether rest or subthreshold aerobic activity provides quicker symptom resolution and return-to-play in comparison to rest for patients diagnosed with a sports-related concussion. After critical analysis was conducted on 25 scholarly articles in chapter three, this fourth and final chapter will address the practice question. In addition, gaps and trends found throughout the research, implications to athletic training practice, and recommendations for further research will be discussed.

Literature Synthesis

The focus of the Critical Review of the Literature has been to answer the question, "Do patients, who have been diagnosed with a sports-related concussion, have decreased symptoms and a quicker return-to-play when subthreshold aerobic exercise is used early in their treatment versus rest alone?" A total of 25 articles were reviewed and appraised in order to answer the question. The following paragraphs will synthesize all 25 articles into three categories: subthreshold aerobic exercise is beneficial for concussion treatment, subthreshold aerobic exercise is neither beneficial or detrimental as a concussion treatment, or recommendation for concussion treatment is rest.

Out of the 25 articles, 15 directly tested and supported subthreshold aerobic activity as a concussion treatment. The *excellent* quality articles in this category include Kurowski et al. (2017), and Leddy et al. (2019). The first study, out of these two, discovered subthreshold aerobic activity was more beneficial than a stretching group for patients experiencing a prolonged recovery (Kurowski et al., 2017). Then, Leddy et al. in 2019 conducted a study which was pivotal to the understanding of subthreshold aerobic activity because it was the first study to use specific parameters to verify the use of subthreshold aerobic activity within the first week of a sustained concussion. All the other studies in this group were of *good* quality and very similar to each other. Of the remaining 13 articles that supported subthreshold aerobic activity, six articles found the intervention reduced symptom severity (Lal et al., 2018; Chrisman et al., 2019; Micay et al., 2018; Dobney et al., 2018; Howell et. al, 2020 & Howell et al., 2016). Two articles found cognition was positively impacted due to subthreshold aerobic activity. Mychasiuk et al. (2016) concluded telomere length and gene expressions found in the hippocampus and prefrontal cortex reduced recovery time in rats who were in the exercise group. Gladstone et al. (2019) saw improvements in learning and memory scores and believes it was due to an increase in nerve growth factor and vascular endothelial growth factor when the patients exercised. Four articles conducted their research with the focus on how patients respond to subthreshold aerobic activity within the first week and found activity within one week was beneficial for recovery (Mychasiuk et al., 2016; Willer et al., 2019; Lawrence et al., 2018; Grool et al., 2016). Additionally, one study saw benefits of subthreshold aerobic activity based on evaluation of multiple studies (Schneider et al., 2017) and another study concluded subthreshold aerobic activity was helpful for diagnostics as well as general management of concussion (Cordingley et al., 2016).

Seven of the 25 articles did not explicitly find a conclusion to whether or not subthreshold aerobic activity was beneficial. Instead, these articles looked at the safety of subthreshold aerobic activity, determined standard care was better than rest, or concluded rest was not entirely helpful. Five articles were of *good* equality, one was *fair* and one was *excellent*. Leddy et al. (2018) discovered the BCTT was safe to use in order to prescribe subthreshold aerobic activity. This article was of *excellent* quality. Maerlender et al. (2015) also concluded subthreshold aerobic activity was safe to administer. Teel et al. (2018) conducted a study with healthy individuals and had them complete various concussion assessments such as VOMS, subthreshold aerobic activity, and BESS test. Overall, they found the outcomes of the tests were not impacted in any way with healthy individuals which meant no changes needed to be made to scoring of such assessments, and the assessments did not cause any worsening of symptoms. Furthermore, studies by Thomas et al. (2015) and Sufrinko et al. (2017) advocated for standard care instead of prolonged or strict rest. Sufrinko et al. (2017) also added that only standard care for those with symptoms of a concussion was beneficial and not for those with signs of a concussion. The article by Sufrino et al. (2017) was the one article in this section with *fair* quality. Similarly, studies by Gibson et al. (2013), McLeod et al. (2017), and Silverberg and Otamendi (2019) cautioned against too much rest in concussion treatment.

Lastly, three of the 25 articles stated rest was a recommended treatment for concussion rehabilitation. Those studies include Moser et al. (2012), Moser et al. (2015), and Sufrinko et al. (2017). The first two studies are based on each other and came to similar outcomes. The study completed by Moser et al. (2012) found cognitive and physical rest was beneficial for concussion treatment no matter the stage of recovery the athlete was in. The second study, completed by Moser et al. (2015), found one week of rest was helpful for concussion treatment to help with symptom reduction and cognitive functioning in adolescents. Both of these studies are of *good* quality but are also some of the oldest articles included in this Critical Review of the Literature. The last article that advocated for rest is Sufrinko et al. (2017). In this study, the authors looked at two groups of patients diagnosed with a concussion. The first group, as mentioned above, was the symptoms group. The second group was the signs group. Those in the signs group benefited from extended rest; therefore, the recommendation was split for this *fair* quality article.

Current Trends and Gaps in Literature

Throughout this study, multiple trends and gaps were identified. First, the years in which the included articles were conducted is a trend as 23 of the 25 articles were published between the years 2015 and 2020. This shows that the topic of active concussion treatment is heavily being studied and is a relatively new idea. Second, the tests used to assess if subthreshold aerobic activity was beneficial for concussion treatment were similar across the literature. Specifically, PCSS, PCSI, and PCS were used to objectify symptoms, and the ImPACT test was used primarily for evaluating cognitive functionings such as visual memory, verbal memory, and reaction time. However, part of the ImPACT test includes a symptom scoring component. The BCTT was used in four studies to determine an individualized exercise prescription for patients. Another area analyzed throughout the literature was the time between injury and recovery. Though this is not a specific test, it was of particular interest in articles that evaluated rest in comparison to active rehabilitation. Third, the type of subthreshold activity completed in the studies were primarily walking, biking, or jogging via treadmill, elliptical, stationary bike, or outside paths. Fourth, defining subthreshold aerobic activity as 80% of the patient's maximal target heart rate was expressed in five *good* or *excellent* quality articles. However, Dobney et al. (2018) conducted subthreshold aerobic activity in her study at 60% of the patient's maximal target heart rate. Similarly, Teel et al. (2018) had her participants start subthreshold aerobic activity at 60% and slowly build up to a maximum of 80% of their maximal target heart rate. Whether 60% was used or 80%, it appears to have been a preference chosen by those who developed the studies. Finally, the last trend discovered was that aerobic activity was the predominant intervention being assessed in comparison to rest. The only other interventions that surfaced were stretching protocols. When excluding systematic reviews, five articles included this additional group to their study (Chrisman et al., 2019; Gladstone et al., 2019; Kurowski et al., 2017; Leddy et al., 2019; Willer et al., 2019). The focus of this critical review was how subthreshold aerobic exercise or rest affected recovery outcomes for sports related concussions which made the finding of the stretching intervention inconsequential.

Gaps in the literature were present as well. The most common gap was the variations in sample sizes. Populations included in this study ranged from 13 to 2413 participants (Moser et al., 2015; Grool et al., 2016). Large sample sizes were rare, and only two studies exceeded 400 participants (Grool et al. 2016; Dobney et al. 2018). On average, the number of total participants in each study was under 50. This is a problem because studies of few participants are more likely to have errors and can lack depth. Larger population sizes would help with accuracy and identifying outliers. Also, not many *excellent* quality randomized control trials were found in the literature. This is not meant to discredit the many *good* quality RCTs, but *excellent* studies would increase the significance of the findings for this Critical Review of the Literature. Furthermore, the timing in which activity was administered varied significantly. Sometimes treatment would begin within the first week of injury (Micay et al., 2018) yet other times, the treatment did not start until months after the sustained concussion (Moser et al., 2012). Though the results of the treatment were being evaluated, discrepancies of when to initiate the treatment remain unresolved.

Implications for Athletic Training

One responsibility of an athletic trainer is to provide evidence-based concussion care to athletes and patients as needed. This includes an evaluation of the injury, but a treatment plan must also be incorporated. Current protocols for treatment of a sports-related concussion recommends athletes to rest for the first 24 to 48 hours post-concussion, but after that time period, the patient may begin activity as long as their symptoms do not worsen (McCrory et al., 2017). Guidelines for how that should look remain ambiguous in consensus statements, and a study by Silverberg and Otamendi (2019) suggests about 82% of practitioners are still recommending more than two days of rest. This means, either the knowledge in the consensus statement is not known by these individuals, or they are not yet convinced of the use of active rehabilitation for concussion treatment. With the ever changing and advancing medical field, continual learning is necessary as a practitioner. This includes understanding why a certain treatment is being prescribed over another and having current evidence-based research to back the reasoning. This is not only mandated for physicians but athletic trainers as well.

Another implication for athletic trainers is to consider using a subthreshold aerobic exercise protocol as explained in the included articles. Researchers have challenged the treatment of rest through their study of subthreshold aerobic activity. Many of them have used similar protocols which have been both effective and safe for concussion rehabilitation. For example, the protocol often recommends the athlete to exercise aerobically daily or almost daily for a set amount of time, usually around 15 to 20 minutes. In addition, the activity is completed at 60 to 80 percent of the patient's target heart rate. However, exertional testing is done first to see how their body responds to the intervention and if their symptoms worsen. To objectify symptoms, a Visual Analog Scale is used. Prior to exercise, the patient reports their symptoms. If at any time during the test their symptom score increases by two or more in comparison to their prior to exercise symptom score, they must stop activity (Leddy et al., 2019). Otherwise, the test is terminated at 20 minutes. Once the BCTT is finished, the patient's heart rate when the test is terminated is calculated to 80% and becomes the individualized program boundary for their home exercise program. When the patient completes subthreshold aerobic activity at home, the expectation is to stop exercise if a 2-point symptom increase occurs. This is to ensure symptoms are not being exacerbated. Throughout treatment, the patient continues to report how they are feeling to the health care provider and advancements in their treatment are made as the patient improves. When the two interventions, rest and subthreshold aerobic activity, are compared to each other, the patients who participated in subthreshold aerobic activity improved quicker in terms of their symptom scores and duration of injury. Also, two studies found rest made symptoms worse before getting better (Thomas et al., 2015; Sufrinko et al., 2017). A few articles advocate for rest, but none of those articles were comparing rest directly to a subthreshold aerobic activity protocol.

The use of subthreshold aerobic activity is safe and beneficial, and the literature is encouraging athletic trainers and physicians managing concussions to adopt this intervention. It is helpful in patients as soon as a few days after injury and for those who have been struggling for months. Speciality equipment such as treadmills, stationary bikes, and fitness watches were primarily used in the studies evaluated, but walking in a safe, controllable environment works as well. Most everyone has access to walking, making subthreshold aerobic activity a practical and affordable intervention to recommend to all. There are few to no reasons why this intervention should not be introduced and used within athletic training settings to help athletes recover from a sports-related concussion.

Recommendations for Future Research

After summarizing and reviewing 25 research articles, gaps throughout the studies were found which prompted ideas and recommendations for future research. The most common suggestion is to conduct studies with larger sample sizes. More people involved in studies means more accurate findings and suggestions. It also means other trends can be discovered such as differences between gender, race, or age (Micay et al., 2018; Lal et al., 2018). Also, more *excellent* quality randomized control trials are recommended for future research because they have a less likelihood of biases (Schneider et al., 2017). Out of the 25 articles included in this study, 11 were RCTs. Only three additional articles were systematic reviews. This means just over half of the research was in the top two tiers of the "Hierarchy of Evidence for Intervention Studies" chart (Fineout-Overholt et al., 2010). This shows that the general quality of this research is good, but it still has areas for improvement.

Furthermore, the timing of when the aerobic activity was initiated following the concussion injury needs to be the focus of future research. Some of the studies had patients begin aerobic activity within the first week of injury, but other studies had patients who presented symptomatic for months participate in their study too. Since there was great variability between injury and initiation of subthreshold aerobic activity, no implication could be made on when the most optimal time is to start subthreshold aerobic activity following injury. Also, very few articles address subthreshold aerobic activity directly following the 24 to 48-hour rest period (McLeod et al., 2017; Schneider et al., 2017; Micay et al., 2018; Richards, &

Hutchison, 2018). Answers to the timing of when to implement activity has the potential to significantly change current concussion protocol; however, more high-quality studies are needed.

Conclusion

The findings of this Critical Review of the Literature validate the use of subthreshold aerobic activity as a treatment more effective than rest for patients diagnosed with a sports-related concussion. To come to this conclusion, 25 scholarly articles were analyzed using the Bethel University Graduate Nursing Program matrix format and were further evaluated with use of the PEDro Scale, CASP Questionnaire, or a series of four questions (The George Institute for Global Health, n.d.; Raab & Craig, 2016). Twenty-three of the 25 studies either recommended subthreshold activity, demonstrated that it was safe, found participating in an aerobic intervention was not more detrimental than rest, or concluded rest to be harmful in concussion rehabilitation. Three studies recommended rest as a quality intervention for concussion treatment. Due to one article being in favor of both rest and subthreshold aerobic activity, the total number of articles may appear to be 26, but only 25 articles were reviewed. Overall, these studies are challenging current concussion rehabilitation protocol which is exciting as the research indicates subthreshold aerobic activity is benefitting patients by reducing symptoms and decreasing the duration of injury in a more positive way than rest.

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Willer, B. S., Haider, M. N., Bezherano, I., Wilber, C. G., Mannix, R., Kozlowski, K., & Leddy, J. J. (2019). Comparison of rest to aerobic exercise and placebo-like treatment of acute sport-related concussion in male and female adolescents. *Archives of Physical Medicine and Rehabilitation*, *100*(12), 2267–2275. doi: 10.1016/j.apmr.2019.07.003

Appendix A: Literature Review Matrix

Systematic Reviews

<table>
<tr><td colspan="4">Source: Lal, A., Kolakowsky-Hayner, S., Ghajar, J., & Balamane, M. (2018). The effect of physical exercise after a concussion: A systematic review and meta-analysis. The American Journal of Sports Medicine, 46(3), 743-752. doi: 10.1177/0363546517706137</td></tr>
<tr>
<td>Design Methodology/ Purpose
Systematic review and meta-analysis
Purpose:
To conduct a systematic review and meta-analysis on the role of physical exercise on different outcomes in patients.
Method:
A search of 5 databases and a hand search of a few articles were performed. Trial registries were reviewed, and authors of multiple studies were contacted to find additional published or unpublished studies. Randomized controlled trials (RCTs), cohort studies, and before and after studies evaluating the effect of physical exercise, compared with control, in patients with a concussion or mild traumatic brain injury were included.</td>
<td>Sample/ Setting
The search generated 1096 studies. Of these, 14 studies (5 RCTs, 1 propensity score matching study, 3 cohort studies, and 5 before and after studies) met our inclusion criteria.

Level: I

Quality:
Good</td>
<td>Design Instruments
This study evaluated comprehensive systematic reviews and meta-analysis on the role of physical exercise on multiple outcomes in patients with concussions, including the PCSS, Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), and balance, and graded the evidence using the Grading of Recommendations Assessment, Develop-ment and Evaluation (GRADE) process.</td>
<td>Results
Exercise decreased the PCSS score (mean difference, –13.06; 95% CI, –16.57 to –9.55; P \ .00001; I^2 = 44%), percentage of patients with symptoms of a concussion (risk ratio, 0.74; 95% CI, 0.63 to 0.86; P = .0001; I^2 = 0%), and days off work (17.7 days vs 32.2 days, respectively; P \ .05) compared with control. Exercise improved the reaction time component of the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) score without affecting the Balance Error Scoring System (BESS) score and neuropsychological parameters. The Grading of Recommendations Assessment, Development and Evaluation (GRADE) scores were moderate for the PCSS, symptoms, ImPACT, BESS, and neuropsychological tests.</td>
</tr>
<tr><td colspan="4">Recommendation: Physical exercise appears to improve the PCSS score and symptoms in patients with a concussion.</td></tr>
</table>

<table>
<tr><td colspan="4">Source: McLeod, T. C., Lewis, J. H., Whelihan, K., & Bacon, C. E. (2017). Rest and return to activity after sport-related concussion: A systematic review of the literature. Journal of Athletic Training, 52(3), 262–287. doi: 10.4085/1052-6050-51.6.06</td></tr>
<tr><td>Design Methodology/ PurposeSystematic Review
Purpose:
To systematically review the literature regarding rest and return to activity after sport-related concussion.
Method: The study design, patient or participant sample, instrumentation or interventions used, outcome measures, main results, and conclusions were extracted, as appropriate, from each article and entered on a standard data-collection form. Articles were categorized into groups based on their ability to address one of the primary clinical questions of interest: use of rest, rest effectiveness, compliance with recommendations, or outcome after graded return-to activity progression.</td><td>Sample/ Setting40 articles from which data were extracted that were synthesized in the results. These consisted of 9 studies of use of rest, 10 studies of rest effectiveness, 17 studies evaluating compliance with guidelines, and 4 studies of return-to-activity outcomes.

Level: 1

Quality: Good</td><td>Design Instruments Articles were categorized according to the clinical question of interest. The study design; patient or participant sample; instrumentation or interventions used; outcome measures; main results; and conclusions were extracted, as appropriate, from each article and entered on a standard data-collection form.</td><td>ResultsThe main findings suggest that rest is underused by health care providers, recommendations for rest are broad and not specific to individual patients, an initial period of moderate physical and cognitive rest (ex. limited physical activity and light mental activity) may improve outcomes during the acute post-injury phase, significant variability in the use of assessment tools and compliance with recommended return-to- activity guidelines exists.</td></tr>
<tr><td colspan="4">Recommendation: With respect to post-injury management, clinicians need to consider balancing rest and active treatments. Although our findings in this review highlight that too much activity can hinder recovery, they also suggest that strict rest can do the same.</td></tr>
</table>

Source: Schneider, K. J., Leddy, J. J., Guskiewicz, K. M., Seifert, T., McCrea, M., Silverberg, N. D., … Makdissi, M. (2017). Rest and treatment/rehabilitation following sport-related concussion: A systematic review. *British Journal of Sports Medicine*, *51*(12), 930–934. doi: 10.1136/bjsports-2016-097475			
Design Methodology/ Purpose Systematic review **Purpose:** To evaluate the evidence related to two questions: (1) What is the evidence that rest is beneficial following concussion, and is there an optimal duration of rest? (2) What is the evidence that active treatment and rehabilitation is effective for athletes who have experienced SRC? **Method:** The initial search terms used in this systematic review, the inclusion criteria, exclusion criteria and database selection were generated and reviewed by the author group. The draft MEDLINE search strategy was then sent to an expert librarian (KAH) to ensure its completeness and accuracy. This was done according to the PRESS Guideline Statement using the CADTH Peer Review Checklist. Extracted data were synthesized qualitatively.	**Sample/ Setting** Twenty-eight studies met the inclusion criteria (9 regarding the effects of rest and 19 evaluating active treatment). The methodological quality of the literature was limited; only five randomised controlled trials (RCTs) met the eligibility criteria. Those RCTs included rest, cervical and vestibular rehabilitation, subsymptom threshold aerobic exercise and multifaceted collaborative care. **Level**: I **Quality:** Good	**Design Instruments** Two authors independently extracted data for each of the articles and independently evaluated the risk of bias using the Downs and Black (DB) checklist for methodological quality. Data were extracted using standardised tables and included the following: study design, participants (sample size, age, sex, sampling methods), treatment (frequency, inten- sity, type, timing/duration), outcome measures, key findings (point estimates with 95% confidence intervals) and level of evidence (per Oxford Centre for Evidence Based Medicine).	**Results** A brief period (24–48 hours) of cognitive and physical rest is appropriate for most patients. Following this, patients should be encouraged to gradually increase activity. The exact amount and duration of rest are not yet well defined and require further investigation. The data support interventions including cervical and vestibular rehabilitation and multifaceted collaborative care.
Recommendation: Closely monitored subsymptom threshold, submaximal exercise may be of benefit.			

Randomized Control Trials

Source: Chrisman, S. P. D., Whitlock, K. B., Mendoza, J. A., Burton, M. S., Somers, E., Hsu, A., … Rivara, F. P. (2019). Pilot randomized controlled trial of an exercise program requiring minimal in-person visits for youth with persistent sport-related concussion. *Frontiers in Neurology*, *10*(JUN), 1–10. doi: 10.3389/fneur.2019.00623			
Design Methodology/ Purpose Pilot Randomized Control Trial **Purpose:** To evaluate feasibility and acceptability of a sub-threshold exercise program with minimal in-person visits to treat youth with SRC, and explore efficacy for improving concussive symptoms, health-related quality of life, and fear-avoidance. **Method:** All subjects completed assessments at study entry and 6 weeks. The remainder of the assessments were completed online, including weekly assessments of symptoms. Accelerometer assessments were completed for 5– 7 days at baseline and 6 weeks to measure moderate-vigorous physical activity (MVPA) in an objective manner.	**Sample/ Setting** youth 12–18 years old from concussion clinics at Seattle Children's Hospital and an online portal over a period of ~9 months. **Level:** II **Quality:** Good	**Design Instruments** moderate-to-vigorous physical activity pre- and post-intervention using accelerometry, and increased goals weekly via phone contact. We examined feasibility and acceptability using qualitative interviews. We used exponential regression to model differences in trajectory of concussive symptoms by experimental group, and linear regression to model differences in trajectory of health-related quality of life and fear-avoidance of pain by experimental group.	**Results** Thirty-two subjects randomized, 30 completed the study (n = 11 control, n = 19 intervention), 57% female. Youth and parents reported enjoying participating in the study and appreciated the structure and support, as well as the minimal in-person visits. Exponential regression modeling indicated that concussive symptoms declined more rapidly in intervention youth than control (p = 0.02). Health-related quality of life and fear-avoidance.
Recommendation: This study indicates feasibility and potential benefit of a 6-week subthreshold exercise program with minimal in-person visits for youth with persistent concussion. Potential factors that may play a role in improvement such as fear-avoidance deserve further study.			

Source: Gladstone, E., Narad, M. E., Hussain, F., Quatman-Yates, C. C., Hugentobler, J., Wade, S. L., … Kurowski, B. G. (2019). Neurocognitive and quality of life improvements associated with aerobic training for individuals with persistent symptoms after mild traumatic brain injury: Secondary outcome analysis of a pilot randomized clinical trial. *Frontiers in Neurology*, *10*(September), 1–9. doi: 0.3389/fneur.2019.01002			
Design Methodology/ Purpose Pilot Randomized Clinical Trial **Purpose:** To report secondary neurocognitive and quality of life outcomes for management of prolonged symptoms after a mTBI in adolescents. **Method:** Week 0- participants were evaluated for eligibility and completed an aerobic bike test. Week 1- participants were randomized into groups. The aerobic training group repeated the aerobic cycling test to create an exercise program. Participants in the stretching group completed a full- body stretching program. Both groups followed up on a weekly basis, and all participants in the completed 6 weeks of training.	**Sample/ Setting** Thirty adolescents between the ages of 12 and 17 years who sustained a mTBI and had between 4 and 16 weeks of persistent post-concussive symptoms. **Level:** II **Quality:** Good	**Design Instruments** The secondary outcomes assessed included neurocognitive changes in fluid and crystallized age-adjusted cognition using the National Institutes of Health (NIH) toolbox and self and parent-reported total quality of life using the Pediatric Quality of Life Inventory.	**Results** General linear models did not reveal statistically significant differences between groups. Within group analyses using paired t-tests demonstrated improvement in age-adjusted fluid cognition [$t(13) = 3.39$, $p = 0.005$, Cohen's $d = 0.61$] and crystallized cognition[$t(13) = 2.63$, $p = 0.02$, Cohen's $d = 0.70$] within the aerobic training group but no significant improvement within the stretching group. Paired t-tests demonstrated significant improvement in both self-reported and parent-reported total quality of life measures in the aerobic training group.
Recommendation: This exploratory RCT supports that sub- symptom exacerbation aerobic training may potentially have positive effects on the neurocognitive recovery of fluid cognitive abilities such as working memory and executive function skills in adolescents with persistent symptoms after mTBI. Data also suggests that improvements in quality of life may be seen with both stretching and aerobic exercise protocols in this population.			

Source: Kurowski, B. G., Hugentobler, J., Quatman-Yates, C., Taylor, J., Gubanich, P. J., Altaye, M., & Wade, S. L. (2017). Aerobic exercise for adolescents with prolonged symptoms after mild traumatic brain injury: An exploratory randomized clinical trial. *The Journal of Head Trauma Rehabilitation*, *32*(2), 79–89. doi: 10.1097/HTR.0000000000000238			
Design Methodology/ Purpose Partially blinded, pilot RCT of sub-symptom exacerbation aerobic training compared to a full-body stretching program. **Purpose:** To describe the methodology and report primary outcomes of an exploratory randomized clinical trial (RCT) of aerobic training for management of prolonged symptoms after mild traumatic brain injury (mTBI) in adolescents. **Method:** Participants were reassessed for eligibility and randomized to the sub-symptom exacerbation aerobic training or full-body stretching intervention. Home exercise/ stretching programs were developed for both groups and the participants were asked to complete their activities at least 5-6 days per week.	**Sample/ Setting** Thirty adolescents between the ages of 12 and 17 years who sustained a mTBI and had between four and 16 weeks of persistent symptoms. 136 participants met full eligibility criteria and approximately 22% enrolled in the study. **Level:** II **Quality:** Excellent	**Design Instruments** The primary outcome was post injury symptom improvement assessed by the adolescent's self-reported Post Concussion Symptom Inventory (PCSI) repeated for at least six weeks of the intervention. Parent-reported PCSI and adherence are also described.	**Results** Twenty-two percent of eligible participants enrolled in the trial. Repeated measures Analysis of Variance via mixed model analysis demonstrated a significant group by time interaction with self-reported PCSI ratings, indicating a greater rate of improvement in the sub- symptom exacerbation aerobic training compared to the full-body stretching group (F-value = 4.11, p-value = .044). Adherence to the home exercise programs was lower in the sub-symptom exacerbation aerobic training compared to the full-body stretching group (mean (SD) times per week = 4.42 (1.95) versus 5.85 (1.37), $p < .0001$) over the duration of the study.
Recommendation: Findings from this exploratory randomized clinical trial suggest sub-symptom exacerbation aerobic training is potentially beneficial for adolescents with persistent symptoms after mTBI.			

Source: Leddy JJ, Haider MN, Ellis MJ, et al. (2019). Early subthreshold aerobic exercise for sport-related concussion: A randomized clinical trial. *JAMA Pediatr.*173(4):319–325. doi:10.1001/jamapediatrics.2018.4397			
Design Methodology/ Purpose multicenter prospective randomized clinical trial **Purpose:** What is the effectiveness of subsymptom threshold aerobic exercise vs a placebo-like stretching program prescribed to adolescents in the short term after sport-related concussion? **Method:** Male and female adolescent athletes (age 13-18 years) presenting within 10 days of SRC were randomly assigned to aerobic exercise or a placebo-like stretching regimen. Symptoms and time to return-to-play were the outcomes assessed.	**Sample/ Setting** A total of 103 participants were included (aerobic exercise: n = 52; 24 female [46%]; stretching, n = 51; 24 female [47%]) **Level:** II **Quality:** Excellent	**Design Instruments** Both forms of exercise were performed approximately 20 minutes per day, and participants reported daily symptoms and compliance with exercise prescription via a website Measured days from injury to recovery; recovery was defined as being asymptomatic, having recovery confirmed through an assessment by a physician blinded to treatment group, and returning to normal exercise tolerance on treadmill testing. Participants were also classified as having normal (<30 days) or delayed (≥30 days) recovery.	**Results** In this randomized clinical trial of 103 adolescents, those assigned to aerobic exercise recovered faster (13 days) than those assigned to placebo-like stretching (17 days), a significant difference.
Recommendation: Early subthreshold aerobic exercise appears to be an effective treatment for adolescents after sport-related concussion.			

Source: Leddy, J. J., Hinds, A. L., Miecznikowski, J., Darling, S., Matuszak, J., Baker, J. G., … Willer, B. (2018). Safety and prognostic utility of provocative exercise testing in acutely concussed adolescents: A randomized trial. *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine*, *28*(1), 13–20. doi:10.1097/JSM.0000000000000431			
Design Methodology/ Purpose	**Sample/ Setting**	**Design Instruments**	**Results**
Prospective Randomized Control Trial **Purpose:** To evaluate (1) systematic assessment of exercise tolerance in adolescents shortly after sport-related concussion (SRC) and (2) the prognostic utility of such assessment. **Method:** We conducted a randomized controlled trial of provocative exercise testing (BCTT) on the day of clinic presentation (Visit #1) in adolescents who sustained SRC within 1–10 days of injury. We conducted a second follow up visit approximately 14 days after the first visit or approximately 21 days post injury (Visit #2).	Adolescents with SRC (1–9 days from injury). Sixty-five were randomized and 54 completed the study (mean age 15 y, 4 days post injury). **Level:** II **Quality:** Excellent	Buffalo Concussion Treadmill Test Heart rate threshold (HRt) at symptom exacerbation represented level of exercise tolerance. Participants reported symptoms daily and then had follow up BCTT. Days to recovery and typical (≤ 21 days) vs. prolonged recovery (> 21 days). Mixed effects linear models and linear regression techniques examined symptom reports and time to recovery. Linear Regression assessed the association of HRt with recovery time.	Days to recovery ($p=0.7060$) and typical vs. prolonged recovery ($p=0.1195$) were not significantly different between groups. Symptom severity scores decreased in both groups over 14 days ($p<0.0001$), were similar ($p=0.2984$), and did not significantly increase the day after the BCTT ($p=0.1960$). Lower HRt on visit day 1 was strongly associated with prolonged recovery time ($p=0.0032$). Systematic evaluation of exercise tolerance using the BCTT within one week after SRC did not affect recovery. The degree of early exercise intolerance after SRC was important for prognosis. This has implications for school academic and team preparation.
Recommendation: Clinicians can safely assess exercise tolerance using the predetermined stopping criterion of symptom exacerbation on the BCTT in adolescents within the first week after SRC. The degree of early exercise intolerance appears to have prognostic utility and may serve as a physiological biomarker for the severity of concussion. Moreover, return of normal exercise tolerance could serve as a physiological biomarker of concussion recovery. Our data show that the BCTT is safe and suggest that a low HRt early after concussion identifies those adolescents who are slow to recover.			

<table>
<tr><td colspan="4">Source: Maerlender, A., Rieman, W., Lichtenstein, J., & Condiracci, C. (2015). Programmed physical exertion in recovery from sports-related concussion: A randomized pilot study. Developmental Neuropsychology, 40(5), 273–278. doi: 10.1080/87565641.2015.1067706</td></tr>
<tr><td>Design Methodology/ Purpose
Randomized pilot trial
Purpose:
to determine the effect of moderate levels of prescribed physical exertion on recovery from concussion
Method:
Initial clinical evaluation was completed as soon as possible. When test scores, balance, and symptoms had returned to baseline, the athlete was determined to be recovered. Athletes assigned to the exertion protocol rode a stationary bicycle at a perceived exertion level of “mild” to “moderate.” In the standard condition, athletes were instructed to engage in no systemic exertion beyond the normal activities required for school.</td><td>Sample/ Setting
Twenty-eight recently concussed college athletes were recruited

Level: II

Quality:
Good</td><td>Design Instruments
Five measures were used to assess athletes throughout the study. These included the use of health and demographics questionnaires, the ImPACT (Immediate Post-concussion Assessment and Cognitive Test) neurocognitive test battery, the Borg CR10 RPE scale (Rated Perceived Exertion), the Post-ride symptom change rating: an experimental Likert scale to rate the changes in symptoms after the bike exertion, and Actical actigraphs to measure the amount of physical activity, day and night.</td><td>Results
There was no difference between the distributions or medians for the number of days to injury to the start of study participation. There were also no differences between groups on any of the other independent variables: severity of injury (ImPACT composite and ImPACT symptom total change scores: p-values all >.10: Table 1), or number of previous concussions (independent samples median test, p = .114). Overall, significantly more bike-rides resulted in some level of symptom change (41%) versus no change (59%)): X2 (1) = 4.76, p = .03. There was a 1.8 symptom increase per ride rated in “light” rides (i.e., number of light symptom increases divided by the total number of light exertion rides), a .55 symptom increase in “moderate” rides, and seven symptoms increased per “strenuous” ride.</td></tr>
<tr><td colspan="4">Recommendation: This study provides initial evidence that starting exercise relatively early after injury, and that mild symptom increases should not interfere in recovery. However, vigorous activity was deleterious.</td></tr>
</table>

<table>
<tr><td colspan="4">Source: Micay, R., Richards, D., & Hutchison, M. G. (2018). Feasibility of a postacute structured aerobic exercise intervention following sport concussion in symptomatic adolescents: A randomised controlled study. BMJ Open Sport & Exercise Medicine, 4(1), e000404. doi: 10.1136/bmjsem-2018-000404</td></tr>
<tr><td>Design Methodology/ Purpose
Randomized Control Trial
Purpose:
This study examined the feasibility of implementing a standardized aerobic exercise (AE) intervention in the post-acute stage of SRC recovery in a sample of adolescent students with SRC compared with usual care.
Method:
Symptomatic adolescents with SRC were randomized to one of two groups: Aerobic Exercise (n=8) or Usual Care (n=7). The AE intervention, beginning on day 6 post-injury, comprised eight sessions with progressive increases in intensity and duration on a cycle ergometer. Usual care consisted of rest followed by physician-advised progressions in activity levels in an unsupervised setting.</td><td>Sample/ Setting
Symptomatic adolescents with SRC were randomized to one of two groups: Aerobic Exercise (n=8) or Usual Care (n=7). Total number of final participants was 15.
Aged 14-18.

Level: II

Quality: Good</td><td>Design Instruments
Outcome measures included: (1) Intervention feasibility: symptom status pre-post exercise sessions and completion of intervention and (2) Clinical recovery: symptom status at weeks 1, 2, 3 and 4 post-injury and medical clearance date. The PCSS was used to determine symptom severity.</td><td>Results
The AE group experienced greater symptom resolution compared with the Usual Care Group across the recovery timeline.</td></tr>
<tr><td colspan="4">Recommendation: Post-acute structured aerobic exercise, beginning on day 6 post-injury, appears to be both safe and feasible to administer to symptomatic adolescent patients with SRC. Structured AE appears to be associated with faster resolution of symptoms severity compared with usual care.</td></tr>
</table>

<table>
<tr><td colspan="4">Source: Mychasiuk, R., Hehar, H., Ma, I., Candy, S., & Esser, M. (2016). Reducing the time interval between concussion and voluntary exercise restores motor impairment, short−term memory, and alterations to gene expression. European Journal of Neuroscience, 44(7), 2407-2417. doi: 10.1111/ejn.13360</td></tr>
<tr><td>Design Methodology/ Purpose
Randomized Control Trial
Purpose:
this study examined the effects of voluntary exercise on concussion recovery
Method:
Animals in this study were in-house bred juvenile male and female Sprague Dawley rats. Rats were randomly assigned to receive a mTBI with the Lateral Impact (LI) device or a sham injury. Exercise, behavior, and socialization components were assessed.</td><td>Sample/ Setting
Rats were randomly assigned to one of the conditions, (a)mTBI + Immediate return, (8 M : 8 F); (b)mTBI + 3-day delay, rats (9 M : 8 F); or (c)mTBI + 7-day delay, (8 M : 8 F); (d)sham + Exercise. (20 M: 18 F). Two no-exercise groups that remained in cages of four for the duration of the experiment, (e)sham + No Exercise (8 M: 9 F); and (f)mTBI + No] Exercise (11 M : 9F).

Level: II

Quality: Good</td><td>Design Instruments
Using a translational rodent model of concussion, the influence of exercise on injury-associated behaviors that comprise post-concussive syndrome (PCS) and gene expression changes (bdnf,dnmt1,Igf-1,pgc1 -a,Tert) in prefrontal cortex and hippocampus were examined., Telomere length (TL) was also examined in the laboratory. Rats were killed, and brain tissue was processed for molecular analysis. Time-to-right and beam walking were measured for behavioral analysis.</td><td>Results
The results suggest that exercise initiated within 1–3 days post-concussion significantly improved motor and cognitive functioning but had limited efficacy treating emotional impairments. When deprived of social interaction and exercise, a combination similar to clinical recommendations for rest until symptom resolution, animals did not recover and exhibited impairments similar to typical mTBI animals.</td></tr>
<tr><td colspan="4">Recommendation: Although additional strategies may need to be employed for emotional functioning, these findings support re-evaluation of ‘return-to-play’ guidelines, suggesting that exercise is valuable for the treatment of concussion.</td></tr>
</table>

Source: Sufrinko, A. M., Kontos, A. P., Apps, J. N., McCrea, M., Hickey, R. W., Collins, M. W., & Thomas, D. G. (2017). The effectiveness of prescribed rest depends on initial presentation after concussion. *Journal of Pediatrics*, *185*, 167–172. doi: 10.1016/j.jpeds.2017.02.072			
Design Methodology/ Purpose Randomized Control Trial **Purpose:** To evaluate if patients with signs of injury respond differently to prescribed rest after concussion com- pared with patients with symptoms only. **Method:** Patients completed computerized neurocognitive testing and standardized balance assessment at the emergency department within 24 hours of injury and on follow-up (3 and 10 days). Patients were randomized to rest or usual care and completed activity and symptom diaries for 10 days after injury.	**Sample/ Setting** Children were eligible if they were 11-22 years of age and presented to the ED within 24 hours (median, 3) of a concussion **Level:** II **Quality:** Good	**Design Instruments** PCSS, ImPACT, and the BESS, and Acute Concussion Evaluation tool were used in this study. A series of 2 × 2 ANOVAs with grouping factors of patient group (symptoms, signs) and treatment arm (prescribed rest, standard of care) were used to examine differences on clinical measures. Univariate nonparametric test (ie, c2 with ORs and 95% CIs) was used to examine the association between treatment arm and symptom status 1-9 days after injury.	**Results** A 2 × 2 factorial ANOVA revealed a significant patient group × treatment arm interaction for symptom score at 3 days after injury ($F = 6.31$, $P = .01$, h2 = 0.07). Prescribed rest increased the likelihood of still being symptomatic at days 1-6 and 8 ($P < .05$) for the symptoms group. Rest was beneficial for patients in the signs group on verbal memory performance ($t = -2.28$, $P = .029$), but not for the symptoms group.
Recommendation: Compared with patients with signs of injury, patients with predominantly symptoms were more likely to remain symptomatic after injury if prescribed rest, whereas patients with signs of injury benefited from rest after a concussion. Individualized treatment planning after concussion should start in the emergency department.			

Source: Teel, E. F., Register-Mihalik, J. K., Appelbaum L. G., Battaglini, C. L., Carneiro, K. A., Guskiewicz, K. M., . . . Mihalik, J. P., (2018). Randomized controlled trial evaluating aerobic training and common sport-related concussion outcomes in healthy participants. *Journal of Athletic Training, 53*(12), 1156-1165. doi: 10.4085/1062-6050-7-18			
Design Methodology/ Purpose Randomized Control Trial **Purpose:** To investigate the effects of a brief aerobic exercise intervention on clinical concussion outcomes in healthy, active participants. **Method:** Intervention(s): Participants were randomized into the acute concussion therapy intervention (ACTIVE) training or non-training group. All participants completed symptom, cognitive, balance, and vision assessments during 2 test sessions approximately 14 days apart. Participants randomized to ACTIVE training completed six 30-minute exercise sessions that progressed from 60% to 80% of individualized maximal oxygen consumption (˙Vo2max) across test sessions, while the non-training	**Sample/ Setting** Convenience sample of university students and staff between the ages of 18 and 30 who participated in at least 30 min. of physical activity 3x a week. Total of 40 healthy, uninjured participants **Level:** II **Quality:** Good	**Design Instruments** The CNS Vital Signs standardized scores, Vestibular/Ocular Motor Screening near-point convergence distance (cm), and Graded Symptom Checklist, Balance Error Scoring System, and Standardized Assessment of Concussion total scores.	**Results** An interaction effect was found for total symptom score (P ¼ .01); the intervention group had improved symptom scores between sessions (session 1: 5.1 ± 5.8; session 2: 1.9 ± 3.6). Cognitive flexibility, executive functioning, reasoning, and total symptom score outcomes were better but composite memory, verbal memory, and near-point convergence distance scores were worse at the second session (all P values < .05). However, few changes exceeded the 80% reliable change indices calculated for this study, and effect sizes were generally small to negligible.
Recommendation: A brief aerobic training protocol had few meaningful effects on clinical concussion assessment in healthy participants, suggesting that current concussion-diagnostic and assessment tools remain clinically stable in response to aerobic exercise training.			

Source: Thomas, D. G., Apps, J. N., Hoffmann, R. G., Mccrea, M., & Hammeke, T. (2015). Benefits of strict rest after acute concussion: A randomized controlled trial. *Pediatrics*, *135*(2), 213–223. doi: 10.1542/peds.2014-0966			
Design Methodology/ Purpose Randomized Control Trial **Purpose:** To determine if recommending strict rest improved concussion recovery and outcome after discharge from the pediatric emergency department (ED). **Method:** Patients were randomized to strict rest for 5 days versus usual care (1–2 days rest, followed by stepwise return to activity). Patients completed a diary used to record physical and mental activity level, calculate energy exertion, and record daily post-concussive symptoms. Sample size calculations were powered to detect clinically meaningful differences in post-concussive symptom, neurocognitive, and balance scores between treatment groups. Linear mixed modeling was used to detect contributions of group assignment to individual recovery trajectory.	**Sample/ Setting** Ninety-nine patients were enrolled; 88 completed all study procedures (45 intervention, 43 control) Patients aged 11 to 22 years presenting to a pediatric ED within 24 hours of concussion were recruited. **Level:** II **Quality:** Good	**Design Instruments** PCSS, ImPACT, BESS Participants received computerized neurocognitive testing and a standardized balance assessment. Trained research assistant arranged follow-up appointments with the participants for 3 and 10 days after their ED visit, at which time repeat neurocognitive tests and balance assessments were administered. 3 day and 7 day journals were kept by the participants to measure symptoms. The journals were reviewed at the last appointment	**Results** Post discharge, both groups reported a 20% decrease in energy exertion and physical activity levels. As expected, the intervention group reported less school and after-school attendance for days 2 to 5 post-concussion. There was no clinically significant difference in neurocognitive or balance outcomes. However, the intervention group reported more daily post-concussive symptoms and slower symptom resolution.
Recommendation: Recommending strict rest for adolescents immediately after concussion offered no added benefit over the usual care. Adolescents' symptom reporting was influenced by recommending strict rest.			

Controlled Trials without Randomization

Source: Moser, R. S., Glatts, C., & Schatz, P. (2012). Efficacy of immediate and delayed cognitive and physical rest for treatment of sports-related concussion. *Journal of Pediatrics*, *161*(5), 922–926. doi: 10.1016/j.jpeds.2012.04.012			
Design Methodology/ Purpose No randomization **Purpose** To evaluate the efficacy of cognitive and physical rest for the treatment of concussion. **Method** (1) completion of intake forms and required paperwork; (2) interview/clinical history exam of patient; (3) completion of ImPACT post-concussion testing; (4) explanation to patient/parents of ImPACT results and prescription of cognitive and physical rest with accompanying verbal instruction, take home report, and instructional handouts; and (5) follow-up examination that included ImPACT post- concussion testing, clinical interview for update in status, and prescription for next steps in recovery process. Patients were followed until cleared to return to normal, pre-concussion activities.	**Sample/ Setting** 49 high school to college-aged individuals (range = 14-23 years) who sustained a concussion and were referred to the Sports Concussion Center of New Jersey for assessment and management. Diagnosis of having a concussion was consistent with the consensus definition. **Level:** III **Quality:** Good	**Design Instruments** ImPACT test online version, was used for the study.	**Results** Participants showed significantly improved performance on Immediate Post-Concussion Assessment and Cognitive Testing and decreased symptom reporting following prescribed cognitive and physical rest ($P < .001$), regardless of the time between concussion and onset of rest ($P = .44$).
Recommendation: These preliminary data suggest that a period of cognitive and physical rest may be a useful means of treating concussion-related symptoms, whether applied soon after a concussion or weeks to months later.			

Source: Moser, R. S., Schatz, P., Glenn, M., Kollias, K. E., & Iverson, G. L. (2015). Examining prescribed rest as treatment for adolescents who are slow to recover from concussion. *Brain Injury*, *29*(1), 58–63. doi: 10.3109/02699052.2014.964771			
Design Methodology/ Purpose Single group, no randomization study **Purpose:** Rest is a widely recommended treatment for concussion, but its utility is unclear following the acute stage of recovery. This study examined the effects of 1-week of prescribed rest in concussed adolescent athletes. **Method:** All participants completed the online version of ImPACT prior to coming to the clinic and again at the clinic. At the time of the initial evaluation at the clinic, a list of cognitive and physical activities to be avoided was provided to the parents of athletes to help monitor rest compliance. The activities to avoid were explained to both athletes and parents. Low exertion activities were recommended such as: listening to relaxing audiobooks, listening to relaxing music, etc. Athletes were advised to avoid activities that might produce a sweat or exacerbate symptoms.	**Sample/ Setting** Participants were 13 adolescent athletes with persistent symptoms following a concussion. All were between the ages of 12-23. More than three-quarters (77%) had self-reported ADHD, learning disability or two prior concussions. **Level:** III **Quality:** Good	**Design Instruments** ImPACT composite scores and symptom scores	**Results** Repeated measures ANOVAs revealed a significant effect of prescribed rest on all ImPACT composite scores and the total symptom score. Post-hoc analyses revealed no significant differences between Time 1 and Time 2, whereas significant differences were present after prescribed rest. Following prescribed rest, having two or more reliably improved cognitive test scores or having improved symptoms was present in eight of the 13 patients (61.5%).
Recommendation: A substantial percentage of adolescents with persistent symptoms following concussion showed improvement in symptoms and cognitive functioning following education, reassurance and 1-week of prescribed rest.			

<table>
<tr><td colspan="4">Source: Willer, B. S., Haider, M. N., Bezherano, I., Wilber, C. G., Mannix, R., Kozlowski, K., & Leddy, J. J. (2019). Comparison of rest to aerobic exercise and placebo-like treatment of acute sport-related concussion in male and female adolescents. Archives of Physical Medicine and Rehabilitation, 100(12), 2267–2275. doi: 10.1016/j.apmr.2019.07.003</td></tr>
<tr>
<td>Design Methodology/ Purpose
Quasi-experimental trial
Purpose:
To compare a sample of adolescents with sport-related concussion who were prescribed rest with 2 arms of a randomized controlled trial comparing aerobic exercise with placebo-like stretching. We also compared sex differences across the 3 approaches to treatment.
Method:
Physicians diagnosed concussion. A patient received 1 point for each sign of injury or indication that performance of test item caused symptoms. All groups were prescribed treatment at the initial clinic visit and followed up with the physician weekly for the first 4 weeks or until recovered, whichever came first.</td>
<td>Sample/ Setting
University concussion management clinics.
Participants:

Adolescent athletes (aged 13-18 years) presenting within 10 days of SRC (mean, 5 days after injury) received a recommendation for rest. Their outcomes were compared with matched samples of adolescents assigned to aerobic exercise or placebo-like stretching group.

Level: III

Quality: Good</td>
<td>Design Instruments
The primary outcome was median days from injury to recovery. The secondary outcome was proportion classified as normal recovery (<30d) or delayed recovery (30d).

BCTT and PCSS was used as well.</td>
<td>Results
The RG recovered in 16 days, which was significantly delayed compared with EG. The PG recovered in 17 days. Four percent of the EG, 14% of the PG, and 13% of the RG had delayed recovery. There was no difference in recovery time or delayed recovery between male participants and female participants across groups. Female participants prescribed rest experienced an increase in symptoms vs the other groups.</td>
</tr>
<tr><td colspan="4">Recommendation: Relative rest and a placebo-like stretching program were very similar in days to recovery and symptom improvement pattern after SRC. Both conditions were less effective than subsymptom threshold aerobic exercise. Female adolescents appear to be susceptible to symptom increase when prescribed rest.</td></tr>
</table>

Case-control or cohort studies

Source: Cordingley, D., Girardin, R., Reimer, K., Ritchie, L., Leiter, J., Russell, K., & Ellis, M. J. (2016). Graded aerobic treadmill testing in pediatric sports-related concussion: Safety, clinical use, and patient outcomes. *Journal of Neurosurgery: Pediatrics*, *18*(6), 693–702. doi: 10.3171/2016.5.PEDS16139			
Design Methodology/ Purpose Retrospective Chart Review **Purpose:** 1) to evaluate the safety, tolerability, and clinical use of graded aerobic treadmill testing in pediatric patients with sports-related concussion (SRC), and 2) to evaluate the clinical outcomes of treatment with a submaximal aerobic exercise program in patients with physiological post-concussion disorder (PCD). **Method:** Patients were referred to a multidisciplinary pediatric concussion program and underwent graded aerobic treadmill testing. Patients with a symptom-limited threshold on treadmill testing (physiological PCD) were treated with an individually tailored submaximal exercise prescription and multidisciplinary targeted therapies.	**Sample/ Setting** One hundred six patients (mean age 15.1 years, range 11–19 years) with SRC. **Level:** IV **Quality:** Good	**Design Instruments** Clinical assessments were carried out by a single neurosurgeon and included clinical history taking, physical examination, and recording specific patient-reported concussion-related symptoms using the Post-Concussion Symptom Scale (PCSS). Graded aerobic treadmill testing using a modified Balke protocol for incremental increases in intensity was used as a diagnostic tool to assess physiological recovery, classify post-concussion syndrome (PCS) subtype, and reassess patients following treatment. The Borg rating of perceived exertion was also used.	**Results** Treadmill testing confirmed physiological recovery in 63 (96.9%) of 65 patients tested, allowing successful return to play in 61 (93.8%). Treadmill testing was used to diagnose physiological PCD in 58 patients and cervicogenic PCD in 1 patient. Of the 41 patients with physiological PCD who had complete follow-up and were treated with tailored submaximal exercise prescription, 37 (90.2%) were classified as clinically improved and 33 (80.5%) successfully returned to sporting activities.
Recommendation: Graded aerobic treadmill testing is a safe, tolerable, and clinically valuable tool that can assist in the evaluation and management of pediatric SRC.			

Source: Dobney, D. M., Grilli, L., Kocilowicz, H., Beaulieu, C., Straub, M., Friedman, D., & Gagnon, I. J. (2018). Is there an optimal time to initiate an active rehabilitation protocol for concussion management in children? A case series. *Journal of Head Trauma Rehabilitation*, *33*(3), E11–E17. doi: 10.1097/HTR.0000000000000339			
Design Methodology/ Purpose Case series **Purpose:** To estimate the time frame during which initiating an active rehabilitation intervention (aerobic exercise, balance, and sport specific skills) after concussion contributed to improvement in symptoms at follow-up in children and adolescents who are slow to recover (symptoms persisting beyond 2 weeks) from concussion. **Method:** Data were obtained from a database collected prospectively from the TBI Program/Concussion Clinic of the MCH. After initial concussion management, participants were instructed to inform the clinic coordinator if symptoms were present 2 weeks following injury for referral to the active rehabilitation intervention, which was then scheduled to start between 3 and 4 weeks pos-tinjury.	**Sample/ Setting** Case series of participants starting active rehabilitation less than 2, 2, 3, 4, 5, or 6 or more weeks post-concussion. A total of 677 children and adolescents with concussion aged 7 to 18 years. Setting was a concussion clinic at a tertiary care pediatric teaching hospital. **Level:** IV **Quality:** Good	**Design Instruments** Symptom severity measured by the 22-item Post-Concussi on Scale (PCS)-revised.	**Results** All patients experienced significant improvement of symptoms while participating in active rehabilitation, irrespective of the start time post-onset. Patients initiating active rehabilitation at 2 (P< .001) or 3 (P= .039) weeks post-injury demonstrated lower symptom severity at follow-up than those starting at 6 weeks or later. Patients starting at 2 weeks had lower symptom severity than patients starting less than 2 (P= .02), 4 (P= .20), or 5 weeks postinjury (P = .04). Lastly, patients starting less than 2 and 6 weeks or more postinjury yielded equivalent outcomes.
Recommendation: The findings support the use of active rehabilitation in children and adolescents who are slow to recover from concussion. Participants starting active rehabilitation less than 2 weeks and up to 6 or more weeks post-concussion demonstrated significant symptom improvements, but improvement was observed in all groups, regardless of the time to start active rehabilitation.			

Source: Gibson, S., Nigrovic, L. E., O'Brien, M., & Meehan, W. P. (2013). The effect of recommending cognitive rest on recovery from sport-related concussion. *Brain Injury*, *27*(7–8), 839–842. doi: 10.3109/02699052.2013.775494			
Design Methodology/ Purpose Retrospective Cohort Study **Purpose:** To determine whether recommending cognitive rest to athletes after a sport-related concussion affects time to symptom resolution. **Method:** The effect of recommending cognitive rest on symptom duration (days) was measured after adjusting for age, gender, initial PCSS score, history of amnesia, history of loss of consciousness and number of previous concussions. Using multivariate logistic regression, independent predictors of prolonged symptoms were identified, defined as 430 days.	**Sample/ Setting** 184 patients who presented to a sports concussion clinic in an academic medical center between 1 November 2007 and 31 July 2009. Participants ranged in age from 8–26 years. Seventy-two percent of the patients were male. **Level:** IV **Quality:** Good	**Design Instruments** PCSS Balance error symptom score Neurocognitive test SCAT2	**Results** Of the 135 study patients with complete medical records, 85 (63%) had cognitive rest recommended. Of those, 79 (59%) had prolonged symptoms. In the multivariate analysis, only initial PCSS score was associated with the duration of concussion symptoms (adjusted odds ratio (AOR)¼1.03; 95% CI¼1.01–1.05). The recommendation for cognitive rest was not significantly associated with time to concussion symptom resolution (AOR¼0.5; 95% CI¼0.18–1.37).
Recommendation: Given the limited evidence regarding the effects of cognitive rest on recovery from concussion, recommendations of prolonged periods of cognitive rest, particularly absences from school, should be approached cautiously.			

Source: Grool, A., Aglipay, M., Momoli, F., Meehan, W., Freedman, S., Yeates, K., . . . Zemek, R. (2016). Association between early participation in physical activity following acute concussion and persistent postconcussive symptoms in children and adolescents. *JAMA, 316*(23), 2504-2514. doi: 10.1001/jama.2016.17396			
Design Methodology/ Purpose Prospective, multicenter cohort study **Purpose:** To investigate the association between participation in physical activity within 7 days post-injury and incidence of persistent post-concussive symptoms (PPCS). **Method:** This research comprises a planned secondary analysis of the Predicting Persistent Postconcussive Problems in Pediatrics (5P) study. Participants were recruited from August 2013 until June 2015 at 9 pediatric emergency departments (EDs). Trained research assistants completed standardized assessments of all patients in the ED. Enrolled patients were offered web-based survey or telephone follow-up at 7 and 28 days post enrollment. Symptom scores were assessed.	**Sample/ Setting** 3063 participants aged 5 – 18 years with ED presentation for acute head injury occurring within the preceding 48 hours, who met concussion diagnosis criteria according to the 2012 Zurich consensus statement. 2413 patients completed the study. **Level:** IV **Quality:** Good	**Design Instruments** Physical activity participation and post-concussive symptom severity were rated using standardized questionnaires in the ED and at days 7 and 28 postinjury. PPCS (3 > or equal to new or worsening symptoms on the post-concussion symptom inventory was assessed at 28 days post enrollment. Early physical activity and PPCS relationships were examined by unadjusted analysis, 1:1 propensity score matching, and inverse probability of treatment weighting (IPTW). Sensitivity analyses examined patients (≥3 symptoms) at day 7.	**Results** The proportion with post-concussion symptoms at 28 days was 28.7% with participation in early physical activity versus 40.1% with conservative rest, a significant difference.
Recommendation: Participation in physical activity within 1 week after injury may benefit symptom recovery following acute concussion in children and adolescents.			

Source: Howell, D. R., Brilliant, A. N., Oldham, J. R., Berkstresser, B., Wang, F., & Meehan, W. P. (2020). Exercise in the first week following concussion among collegiate athletes: Preliminary findings. *Journal of Science and Medicine in Sport*, *23*(2), 112–117. doi: 10.1016/j.jsams.2019.08.294			
Design Methodology/ Purpose Longitudinal cohort **Purpose:** Our purpose was to examine the association between exercise after concussion with symptom severity, postural control, and time to symptom-resolution. **Method:** Patients completed a symptom questionnaire at initial (0.6 ± 0.8 days post-injury) and follow-up (2.9 ± 1.4 days post-injury) evaluations, and a postural control assessment at follow-up. Participants were grouped into those who exercised in between the time of injury and the follow-up evaluation and those who did not. Decisions regarding post-concussion exercise were made by a sports medicine team consisting of a single team physician and athletic trainers.	**Sample/ Setting** Collegiate DI athletes (n = 72; age = 20.2 ± 1.3 years; 46% female) with concussion completed **Level:** IV **Quality:** Good	**Design Instruments** PCSS Single/Dual Task Gait Assessment Modified BESS	**Results** Thirteen athletes were not included in the current study, resulting in an 85% response rate. Thirteen of the athletes who completed the study exercised between evaluations (18%). There was no symptom resolution time difference between groups (median = 13 [IQR = 7–18] days vs. 13 [7–23] days; p = 0.83). Symptom ratings were similar between groups at the acute post-injury assessment (median PCSS = 18.5 [7.5–26] vs. 17 [14–40]; p = 0.21), but a main effect of group after adjusting for time from injury to assessment indicated the exercise group reported lower symptom severity than the no exercise group across both assessments (p = 0.044). The dual-task gait speed of the exercise group was higher than the no exercise group (0.90 ± 0.15 vs. 0.78 ± 0.16 m/s; p = 0.02).
Recommendation: Athletes who were recommended aerobic exercise after concussion did not have worse outcomes than those who were not. Exercise within the first week after concussion does not appear to be associated with detrimental clinical outcomes.			

Source: Howell, D. R., Mannix, R. C., Quinn, B., Taylor, J. A., Tan, C. O., & Meehan, W. P. (2016). Physical activity level and symptom duration are not associated after concussion. *American Journal of Sports Medicine*, *44*(4), 1040–1046. doi: 10.1177/0363546515625045			
Design Methodology/ Purpose Cohort study **Purpose:** To examine the association between physical activity and symptom duration in a cohort of patients after a concussion. **Method:**The questionnaire assessed the post-concussion symptom scale (PCSS) score, previous number of concussions, presence of the loss of consciousness or amnesia at the time of injury, and prior treatment for headaches. During each follow-up clinic visit, physical activity level was self-reported. A Cox proportional hazard model was constructed to determine the association between symptom duration, initial clinic visit responses, and self-reported physical activity level after the injury.	**Sample/ Setting** This study included 364 patients who were diagnosed with a concussion, were seen by a physician within 3 weeks of injury and completed a questionnaire at the initial clinic visit. Study participants ranged in age from 8 to 27 years (mean age, 15.0 years) and had sustained a mean of 0.8 prior concussions; 222 patients (61%) were male. **Level:** IV **Quality:** Good	**Design Instruments** Symptoms were assessed using the PCSS, a 22-symptom inventory adapted from the Standardized Concussion Assessment Tool version 2. Activity was assessed during the initial clinic visit and during each regularly scheduled follow-up examination. During follow-up visits, patients described their average level of physical activity (Table 1) and cognitive activity since the previous clinic visit using standardized scales. This physical activity scale was adapted from the graduated return-to-play protocol described by the Consensus Statement on Concussion in Sport.	**Results** On initial examination, the mean PCSS score was 34.7. The mean symptom duration was 48.9 days after the injury. Among the variables included in the model, initial PCSS score and female sex were independently associated with symptom duration, while physical activity level after the injury was not. For participants aged between 13 and 18 years, however, higher levels of physical activity after the injury were associated with a shorter symptom duration.
Recommendation: Results from this study indicate that physical activity after the injury may not be universally detrimental to the recovery of concussion symptoms.			

Source: Lawrence, D.W., Richards, D., Comper, P., & Hutchison, M.G. (2018). Earlier time to aerobic exercise is associated with faster recovery following acute sport concussion. *PLoS ONE, 13*(4): e0196062. doi: 10.1371/journal.pone.0196062			
Design Methodology/ Purpose retrospective study design with consecutive sampling **Purpose:** To determine whether earlier time to initiation of aerobic exercise following acute concussion is associated with time to full return to (1) sport and (2) school or work. **Method:** All acute physician diagnosed concussions presenting to an academic sports medicine clinic from October 2016 to December 2017. The academic sports medicine clinic has ten active sports medicine physicians, all of whom provide concussion care in alignment with the most recent Consensus Statement on Concussion in Sport. Although data collection was retrospective with respect to the time of the study, coders were blinded to the main out- come variables when collecting data on exposure variables.	**Sample/ Setting** A total of 253 acute concussions [median (IQR) age, 17.0 (15.0–20.0) years; 148 (58.5%) males] were included in this study **Level**: IV **Quality:** Good	**Design Instruments** The primary exposure of interest was the time (days from injury) to the initiation of aerobic exercise following concussion Age, sex, symptom severity, time to first assessment, LOC, PTA, history of psychiatric condition, and history of a headache disorder were also acquired	**Results** Initiating aerobic exercise at 3 and 7 days following injury was associated with a respective 36.5% (HR, 0.63; 95% CI, 0.53–0.76) and 73.2% (HR, 0.27; 95% CI, 0.16–0.45) reduced probability of faster full return to sport compared to within 1 day; and a respective 45.9% (HR, 0.54; 95% CI, 0.44–0.66) and 83.1% (HR, 0.17; 95% CI, 0.10–0.30) reduced probability of faster full return. Additionally, concussion history, symptom severity, LOC deleteriously influenced concussion recovery.
Recommendation: Earlier initiation of aerobic exercise was associated with faster full return to sport and school or work. This study provides greater insight into the benefits and safety of aerobic exercise within the first week of the injury.			

Source: Silverberg, N. D., & Otamendi, T. (2019). Advice to rest for more than 2 days after mild traumatic brain injury is associated with delayed return to productivity: A case-control study. *Frontiers in Neurology*, *10*(APR), 1–6. doi: 10.3389/fneur.2019.00362			
Design Methodology/ Purpose Case-control design **Purpose:** (i) document the current state of deimplementation of prolonged rest advice, (ii) identify patient characteristics associated with receiving this advice, and (iii) examine the relationship between exposure to this advice and clinical outcomes. **Method:** Participants were prospectively recruited from two concussion clinics in Canada's public health care system. They completed self-report measures at clinic intake as well as a questionnaire with patient, injury, and recovery characteristics and the question: "Were you advised by at least one health professional to rest for more than 2 days after your injury?	**Sample/ Setting** (1) aged 18–60 years; (2) sustained a physician diagnosed mTBI <3 months ago; (3) fluent in English; and (4) had a family physician or could identify a walk-in clinic where they access primary care (for the parent study). **Level:** IV **Quality:** Good	**Design Instruments** Rivermead Post-concussion Symptom Questionnaire Personal Health Questionnaire-9 Generalized Anxiety Disorder-7	**Results** Of the eligible participants, 82.9% reported being advised to rest for more than 2 days (exposure group). This advice was not associated with patient characteristics. In generalized linear modeling, exposure to prolonged rest advice predicted return to productivity status at intake (B = −1.06, chi-squared(1) = 5.28, p = 0.02; 64.5% in the exposure group vs. 40.0% in the control were on leave from work/school at the time of clinic intake, 19.8 vs. 24% had partially returned, and 11.6 vs. 24% had fully returned to work/school). The exposure group had marginally (non-significantly) higher post-concussion, depression, and anxiety symptoms.
Recommendation: This study supports growing evidence that prolonged rest after mTBI is generally unhelpful, as patients in the exposure group were less likely to have resumed work/school at 1–2 months post-injury.			

Appendix B: Quality Assessments and Level of Evidence Chart

PEDro scale

1. eligibility criteria were specified	no ❑ yes ❑ where:
2. subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	no ❑ yes ❑ where:
3. allocation was concealed	no ❑ yes ❑ where:
4. the groups were similar at baseline regarding the most important prognostic indicators	no ❑ yes ❑ where:
5. there was blinding of all subjects	no ❑ yes ❑ where:
6. there was blinding of all therapists who administered the therapy	no ❑ yes ❑ where:
7. there was blinding of all assessors who measured at least one key outcome	no ❑ yes ❑ where:
8. measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	no ❑ yes ❑ where:
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	no ❑ yes ❑ where:
10. the results of between-group statistical comparisons are reported for at least one key outcome	no ❑ yes ❑ where:
11. the study provides both point measures and measures of variability for at least one key outcome	no ❑ yes ❑ where:

Critical Appraisal Skills Programme (CASP) Questions

Answer each question as *yes, no,* or *uncertain.*

_______ 1. **Did the study address a clearly focused issue?** Did the authors clearly define the population and risk factors? Did the study try to detect a benefit or effect, and was this reported?

_______ 2. **Did the authors use an appropriate method to answer their question?** A prognostic study should use a cohort or case report. Are these appropriate methods for the question being reviewed?

_______ 3. **Was the cohort recruited in an acceptable way?** Was the selection of participants explained? Do they represent a defined population, and is that population representative of the population you are working with? Was there anything special about the population? Were all applicable persons included in the study?

_______ 4. **Was the exposure accurately measured to minimize bias?** Were subjective or objective measures used? Objective are preferred to minimize potential bias. Have the measures been validated?

_______ 5. **Was the outcome accurately measured to minimize bias?** Were outcomes measured subjectively or objectively? Has a reliable system been established for detecting the conditions of interest (disease, injury)? Were subjects and assessors blinded to the exposure or outcomes, and in this case, is that important?

_______ 6. **(a) Have the authors identified all important confounding factors? (b) Have they taken account of the confounding factors in the design or analysis?** Are there other confounding factors you can list? Has the author accounted for confounding factors in the design or results?

_______ 7. **(a) Was the follow-up of subjects complete enough? (b) Was the follow-up long enough?** Was follow-up thorough, and was it long enough to allow symptoms to present or resolve? Did the author report the number of people lost to follow up on? They may have had a different outcome.

Critical Appraisal Skills Programme (CASP) Questions *(continued)*

________ 8. **Are the results of this study clearly stated?** What are the bottom line results, the take-home message? Are the r, p, and R^2 values reported?

________ 9. **Are the results precise?** Are all relevant values reported in a fashion that allows interpretation?

________ 10. **Do you believe the results?** Are the methods well described? Did you see anything flawed in the methods? Could the outcome be a result of confounding variables, bias, or chance?

________ 11. **Can the results be applied to the local population?** Are the subjects in the study similar to your patient?

________ 12. **Do the results of this study fit with other available evidence?** Is this the only study that supports the result? Is it in contrast to a greater number of other studies?

Hierarchy of Evidence for Intervention Studies

Type of evidence	Level of evidence	Description
Systematic review or meta-analysis	I	A synthesis of evidence from all relevant randomized controlled trials.
Randomized controlled trial	II	An experiment in which subjects are randomized to a treatment group or control group.
Controlled trial without randomization	III	An experiment in which subjects are nonrandomly assigned to a treatment group or control group.
Case-control or cohort study	IV	Case-control study: a comparison of subjects with a condition (case) with those who don't have the condition (control) to determine characteristics that might predict the condition. Cohort study: an observation of a group(s) (cohort[s]) to determine the development of an outcome(s) such as a disease.
Systematic review of qualitative or descriptive studies	V	A synthesis of evidence from qualitative or descriptive studies to answer a clinical question.
Qualitative or descriptive study	VI	Qualitative study: gathers data on human behavior to understand *why* and *how* decisions are made. Descriptive study: provides background information on the *what*, *where*, and *when* of a topic of interest.
Expert opinion or consensus	VII	Authoritative opinion of expert committee.

Adapted with permission from Melnyk BM, Fineout-Overholt E, editors. Evidence-based practice in nursing and healthcare: a guide to best practice [forthcoming]. 2nd ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams and Wilkins.

Appendix C: Buffalo Concussion Treadmill Test Protocol

1. Patient rates symptoms on Visual Analog Scale (VAS, 0-10).
2. Resting heart rate taken
    a. Use heart rate monitor
    b. Patient seated `
    c. After 2 minutes of rest
3. Patient begins treadmill test
    a. Speed set at 3.2 mph
        i. 3.6 mph if patient is 5’10” or taller
    b. 0 degree incline
4. After each minute, treadmill incline is increased by one degree.
    a. Continue this process for the first 15 minutes
5. After 15 minutes, begin increasing speed.
    a. 0.4 mph every minute
6. Record Heart rate, VAS, and Borg Rating of Perceived Exertion (RPE) every minute
    a. Patient should be instructed to not push through symptoms
7. Stop test at symptom exacerbation (3+ symptom increase from pre-exercise VAS) or voluntary exhaustion (RPE of 17 or above).
8. Conclude with 2 minute cool down
9. Document heart rate at end of test