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Active Therapies in the Management of Concussion and Post-Concussion Syndrome

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by

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Abstract

The purpose of this research and literature review is to evaluate the recently completed literature to provide guidance to medical providers of the safest and most efficacious treatment options for adolescent patients with concussion and post-concussion syndrome. The literature was searched for studies directly related to adolescents and active therapies such as physical therapy, vestibular rehabilitation, exertional therapy, and cognitive behavioral therapy. The search time frame implemented was studies completed within the last ten years. Ten studies met the final criteria. The research shows a substantial benefit for immediate cognitive and physical rest following a mTBI. The research suggests that 24-48 hours of immediate cognitive and physical rest provides the most benefit for patients. In addition, the research reviewed has shown that earlier implementation of active therapies such as aerobic exercise, physical therapy, and cognitive behavioral therapy can benefit patients recovering from a mTBI and those with post-concussion syndrome.

Keywords: concussion, post-concussion syndrome, physical therapy, vestibular rehabilitation, exertional therapy, and cognitive behavioral therapy.

Introduction

Sports related concussions (SRC) are recognized as a major health concern in young athletes. Although there is no current consensus on the definition of concussion, one cannot deny the prevalence and clinical burden it presents. According to the Centers for Disease Control (CDC, 2018) between the years 2005 to 2009 pediatric concussion or mild traumatic brain injury (mTBI) accounted for two million outpatient visits and almost three million emergency department visits. In 2018, the CDC published clinical practice guidelines relating to the diagnosis and management of mTBI. Despite the availability of these guidelines, the practice of managing concussion treatment is highly debated. The purpose of this study is to evaluate the recently completed literature to provide guidance to medical providers in the safest and most efficacious treatment options for patients with concussion and post-concussion syndrome. For the purposes of this literature review, mild traumatic brain injury is defined as an acute brain injury resulting from mechanical energy to the head from external physical forces; post-concussion syndrome is defined as symptoms that last > 30 days or longer following a mTBI.

Statement of the Problem

Signs and symptoms of sports related concussions can include somatic, vestibular, oculomotor, cognitive, emotional, and sleep complaints (Halstead, Mark, Walter, Kevin, Moffatt & Kody, 2018). Because concussion symptoms often interfere with academics, relationships, social endeavors, and of course athletics, it is imperative that providers accurately diagnose and manage these patients to prevent lifelong burden. Historically, physical and cognitive rest have been mainstays in the treatment of both concussion and post-concussion syndrome. Recently, prolonged rest has been challenged in the treatment of both concussion and post-concussion syndrome. With new research and data becoming available, providers need to be informed on the

latest studies that will provide guidance in the management of the adolescent population with concussion and post-concussion syndrome.

Research Question

In adolescents with acute concussion or post-concussion syndrome, what is the effect of active therapies compared to traditionally prescribed cognitive and physical rest in improvement of symptoms?

Methods

A literature review will be performed using the following resources; PubMed, ClinicalKey, DynaMed, and Embase. Both keywords and Medical Subject Headings (MeSH) terms were used to obtain literature discussing concussions, post-concussion syndrome, and the management of each. The literature was further searched for studies directly related to active therapies such as physical therapy, vestibular rehabilitation, exertional therapy, and cognitive behavioral therapy. The search time frame implemented was studies completed within the last ten years, so several studies completed before then were excluded. Studies completed in the United States and Canada were included. The target population was adolescents; however, limited studies were available for some themes that pertained only to adolescents. Studies that specifically focused on adolescents were chosen when able, with some studies including adults up to age 30 to allow for larger sample sizes. Ten studies met the final criteria.

Literature Review

This literature review includes extensive research regarding the implementation of active therapies, following a concussion, sooner than historically recommended. Of the studies reviewed, therapies implemented included individualized physical therapy, vestibular rehabilitation, cognitive behavioral therapy, and aerobic exercise. Study objectives included the

assessment of appropriate duration of reduced physical and cognitive activity after concussion, safety and efficacy of aerobic exercise compared to low-impact exercise, and the safety and efficacy of psychotherapy implemented during concussion recovery. The research was evaluated further to include the aforementioned objectives in relation to post-concussion syndrome management. It is important to note that while the growing body of research regarding this topic is vast, there is an ethical limitation on performing true randomized controlled trials. To do so, researchers would have to directly apply the same amount of force required to produce a concussion to patients and subsequently study their results compared to controls who did not sustain the previously determined and measured mechanical injury to the head.

Efficacy of Physical and Cognitive Rest in Concussion Management

Historically, cognitive and physical rest have been mainstays in the treatment of acute mTBI. The clinical practice guidelines provided by the CDC regarding the management of acute concussion in adolescents recommends that patients should partake in restricted physical and cognitive activity during the first several days following a mTBI (moderate level evidence) (CDC, 2018). The rationale for this recommendation is two-fold. First, there is the potential for reinjury that could result in poorer prognosis if patients do not rest. Second, prior evidence has shown that rest has accelerated patient recovery times.

In an observational study completed by Taubman, Rosen, McHugh, Grady, and Elci (2016), researchers set out to examine the effects of immediate cognitive and physical rest on recovery time following concussion, versus those who did not implement cognitive and physical rest immediately after injury. Participants in the study included children between the ages of 11 and 19 who were diagnosed with a concussion. Mechanism of concussion was not defined.

The methods of this study included an initial diagnosis of concussion followed by physical examination and baseline Post Concussion Symptom Scale (PCSS). All patients were prescribed immediate cognitive and physical rest regardless of the time between injury and presentation/diagnosis. Patients were then instructed to continue with cognitive and physical rest until asymptomatic. At which time they were instructed to gradually return to normal activities. This involved returning to school for half days and eventually returning for full days. Patients were examined closely during this time with weekly visits. Once physical examination was unremarkable, weekly telephone contact was considered sufficient. Recovery was defined as returning to school full time with no academic limitations and no educational accommodation requirements. Quick recovery was defined as returning to school within 30 days, prolonged recovery was defined as returning to school after 30 days post injury. Statistical significance was defined as $p < 0.05$.

A total of 95 patients completed the study, 58 patients initiated cognitive and physical rest on the day of injury. The remaining 37 patients did not initiate cognitive or physical rest and returned to school shortly after injury while still symptomatic. The results of this observational study included an increased likelihood of prolonged recovery for those who did not initiate immediate cognitive and physical rest ($p=0.016$).

The CDC (2018) recommends cognitive and physical rest for a duration of several days following a mTBI. There is currently no consensus on the appropriate duration of cognitive and physical rest following a mTBI. While this may be patient-dependent, further evidence is needed to support a more clear and concise duration recommendation.

In a prospective randomized controlled trial of patients presenting to the Children's Hospital of Wisconsin Emergency Department and Trauma Center, Thomas, Apps, Hoffmann,

McCrea, and Hammeke (2015) set out to investigate the effectiveness of recommending five days of strict rest compared to 24 or 48 hours of rest on patients' outcomes after discharge from the emergency department (ED) with acute concussion.

The methods of this study included the enrollment of adolescent patients (ages 11-22) who had presented to the ED within 24 hours of injury with a diagnosed concussion or mild traumatic brain injury (mTBI). Patients were then assessed using the Balance Error Scoring System (BESS) and Immediate Post Concussion Assessment and Cognitive Testing (ImPACT) and subsequently randomized into either the strict rest (5 days, intervention) or usual care (24-48 hours rest, control) groups. Patients were given a three-day activity diary to record both physical and mental activity as well as a standard 19-symptom Post-Concussive Symptom Scale (PCSS). After three days, patients in both groups were asked to follow up with their provider to complete another BESS and ImPACT assessment, they were then given another activity diary. This was repeated again at a 10-day follow up appointment and the study was concluded.

There were 88 participants who completed the follow-up procedures. The intervention group included 45 patients; the control group included 43 patients. There were no significant differences in mechanism of injury, symptoms at presentation, history of migraine headaches, previous mTBI, or ED evaluation and treatment. Recreational sports, mostly football, were the most common mechanism of injury. The study found that 60% of patients experienced symptom resolution (defined as PCSS < 7) during the 10 day follow up period. It did take three days longer for half of the patients in the intervention group to report symptom resolution compared to the control group. The intervention group also reported greater total PCSS scores over the follow up period (187.9 intervention vs. 131.9 control, $p < .03$). The study did not find significant

differences between the intervention and control group in ImPACT and BESS scores at 3 or 10 days.

Efficacy of Physical Activity in Concussion Management

The pathophysiology of concussion has been described by Giza and Hovda (2014) as a neurometabolic cascade that results in impairments in neurotransmission, impaired axonal transport, and oxidative stress. Emerging evidence suggests that physical activity may demonstrate a protective effect following the neurometabolic cascade from an acute mTBI.

Lawrence, Richards, Comper, and Hutchinson (2018) conducted a retrospective study to examine whether earlier time to initiation of aerobic exercise following acute concussion effected time to recovery. All participants were diagnosed with SRC and presented within 14 days or less of the injury. The primary exposure of interest was the time to the initiation of aerobic exercise following concussion, either self-initiated or physician prescribed. Self-initiated aerobic exercise was defined as jogging, running, swimming, cycling, or utilization of stationary aerobic equipment. Physician prescribed activity consisted of stationary bike use that followed a graded return to activity guideline provided by the Consensus Statement on Concussion in Sport from the 5th International Conference on Concussion in Sport, held in Berlin, October 2016.

A total of 253 acute concussions were included in this study. Most injuries occurred during ice hockey, followed by rugby, football, and soccer. The results showed that for each successive day delaying initiation of aerobic exercise, individuals had longer recovery trajectories. For example, patients who initiated exercise on day three post-injury reduced their probability of full return to sport by 36.5% (HR, 0.63; 95% CI, 0.56-0.76), whereas patients who initiated exercise on day 14 post-injury reduced their probability of full return to sport by 88.9% (HR, 0.11; 95% CI, 0.06-0.22). Return to school showed similar results, patients who initiated

exercise on day three post-injury reduced their probability of full return to school by 45.9% (HR, 0.54; 95% CI, 0.44-0.66), whereas patients who initiated exercise on day 14 post-injury reduced their probability of full return to school by 94.7% (HR, 0.05; 95% CI, 0.03-0.11).

Leddy et al. (2019) hypothesized that early sub-symptom threshold aerobic exercise would speed recovery from sports-related concussions. The basis of this hypothesis was founded on the proposed (but still ultimately unknown) mechanism of exercise intolerance after SRC. It is thought that dysregulation of the autonomic nervous system, reduced cardiac stroke volume, and impaired cerebral blood flow are causative factors. Therefore, it is reasonable to consider that aerobic exercise, which has beneficial effects on autonomic regulation, cardiac stroke volume, and cerebral blood flow, could help patients with concussions recover more rapidly.

Leddy et al. (2019) completed a parallel randomized clinical trial of sub-symptom threshold aerobic exercise treatment vs. a placebo-like program of stretching exercises prescribed in the acute phase after SRC on time to recovery in adolescent athletes. Male and female athletes presenting within 10 days of SRC were evaluated by an experienced sports medicine physician who diagnosed the concussion according to the International Concussion in Sport Group Criteria. A total of 103 participants met the inclusion criteria and completed the study with 52 participants in the aerobic exercise group and 51 participants in the stretching group. The sub-symptom threshold aerobic exercise prescription target heart rate was calculated as 80% of the heart rate achieved at symptom exacerbation on the Buffalo Concussion Treadmill Test (BCTT) completed at their first visit. Participants were told to stop their exercise session if their symptoms increased by two or more points from their pre-exercise symptom level or at 20 minutes, whichever came first. Participants in the stretching group were provided with a booklet that contained a gentle, whole-body, progressive stretching program that would not considerably elevate their heart rate

to perform for 20 minutes per day. Both groups completed repeat BCTTs at their weekly follow ups and their corresponding programs were advanced with new target heart rate determinations. Participants then recorded their symptoms each evening between 7 pm and 10 pm on a password-protected website using the Post-Concussion Symptom Scale. To enhance compliance, participants received daily text-message reminders.

Aerobic exercise participants recovered in a median of 13 days, whereas stretching participants recovered in 17 days ($p = .009$). The results of this study indicate that aerobic exercise safely improved recovery from SRC in adolescents with concussion symptoms compared with a placebo-like stretching intervention. There was also an indication that aerobic exercise might also prevent prolonged recovery (> 30 days), however this did not reach statistical significance that was previously defined as $p < .05$.

Efficacy of Physical Therapy in Concussion Management

Given the historically prescribed active and cognitive rest, there has not yet been a study that examines the utilization of physical therapy strategies prior to three weeks post injury. Lennon et al. (2018) completed a retrospective observational study with the intent of examining the safety and recovery outcomes of a multimodal, impairment-based physical therapy approach to management of acute concussions implemented at varying times post-injury.

The methods of this study included the procurement of medical records from a large metropolitan children's hospital from June 11, 2014 to January 31, 2016. The authors received approval from the Institutional Review Board to compile medical records of patients who had received outpatient physical therapy services for the management of concussion-related complaints. The target population was adolescents and young adults ages 12-21. The mean age for all participants was 14.77 years (SD 1.94). One hundred twenty patient records met the final

inclusion and exclusion criteria. The records were then categorized into three cohorts based on the timing of physical therapy initiation: 0-20 days post injury (early intervention), 21-41 days post injury (middle intervention), and 42 or more days post injury (late intervention). The primary outcome measure observed was the Post-Concussion Symptom Inventory (PSCI). This measure was observed to assess the effectiveness of physical therapy on recovery outcomes. A higher score indicates a higher totality and severity of symptoms while a score of zero indicates symptom absence (Sady, Vaughan & Gioia, 2014). To assess safety, each patient's medical record was examined for unplanned visits to a health care provider, urgent care clinic, or emergency department. If a patient had an unplanned visit to any of the aforementioned locations, it was flagged as a potential adverse event and further evaluated for relation to physical therapy.

Patients were evaluated and treated by one of 32 physical therapists who clinically determined which interventions were appropriate and safe for each individual patient. Thirty-three individuals were categorized into the early intervention group, 39 were categorized into the middle intervention group, and 48 were categorized into the late intervention group.

In observation of effectiveness of physical therapy and treatment outcomes, the three intervention groups did not statistically differ regarding their initial ($p=0.50$), final ($p=0.13$), or change in ($p=0.38$) PCSI scores.

In observation of physical therapy safety, it was found that seven of the 120 individuals had an unplanned visit to a healthcare provider within one week of their physical therapy session. The authors suggest that because these visits occurred two days after their physical therapy session, it is unlikely that the symptom exacerbations were directly related. There was no p value associated with this finding which can be considered as a limitation and possible bias.

Patients often report vestibulo-oculomotor complaints such as dizziness following a mTBI. In a systematic review completed by Murray, Meldrum, and Lennon (2016) the objectives were as follows: first, they set out to evaluate the published literature that supported to use of vestibular rehabilitation in the treatment of a mTBI/concussion. Second, they set out to determine if specific outcome measures could be identified in the vestibular rehabilitation treatment models.

The methods of this study included a systematic search of the literature guided by the PRISMA guidelines. The following databases were searched: PubMed, CINAHL, EMBASE, SPORTDiscus, Web of Science, and PEDRO. Articles were included if the following criteria were met: the article included original research, the patient population were those with a concussion/mTBI and vestibular symptoms, intervention utilized detailed vestibular rehabilitation and measurement of outcomes pre-vestibular rehabilitation and post-vestibular rehabilitation. The search yielded over 3,000 articles. Ten articles met the final inclusion criteria including two randomized control trials, two prospective cohort studies, one retrospective study and five case studies.

All studies but one reported improvement in outcome measures of interest (dizziness, gaze stabilization, balance and gait, and return to work/sport) with vestibular rehabilitation, and no adverse effects to the interventions were documented in any of the studies. Optimal time to begin treatment following SRC and duration of treatment remains unclear.

Schneider et al. (2014) conducted a randomized control trial of patients between the ages of 12 and 30 years who presented to the University of Calgary Sport Medicine Centre with a diagnosis of SRC. The goal of this study was to examine whether a combination of vestibular

rehabilitation and physiotherapy treatment for the cervical spine decreases patients' time to medical clearance for return to school/return to play.

Twenty-nine individuals met the inclusion criteria of the study and fully participated. The intervention group included 15 individuals while the control group included 14 individuals. Both groups met weekly with a physiotherapist for eight weeks or until the time of medical clearance to return to sport. At these visits, both groups performed non-provocative range of motion exercises, stretching, and postural education. The intervention group received an additional, individually designed combination of cervical spine physiotherapy and vestibular rehabilitation. The primary outcome measure of the study was the number of days from treatment initiation to medical clearance and return to sport declaration. Medical clearance was determined by a sport medicine physician who was blinded to the treatment group and reflected an improvement in symptoms of dizziness, headache and/or neck pain, and overall clinical improvement. Secondary outcome measures were evaluated at initiation of treatment and at the time of medical clearance or 8 weeks. Secondary measures included: 11-point Numeric Pain Rating Scale score, Activities-specific Balance Confidence Scale, Dizziness Handicap Index, Sport Concussion Assessment Tool 2 (SCAT2), Dynamic Visual Acuity, Head Thrust Test, modified Motion Sensitivity Test, Functional Gait Assessment, Cervical Flexor Endurance (CFE), and Joint Position Error (JPE) test.

Results of this study included 11 of the 15 individuals in the intervention group being medically cleared for return to sport within eight weeks of treatment. One of the 14 individuals in the control group was medically cleared for return to sport within eight weeks of treatment. Thus, a greater proportion of individuals in the intervention group were medically cleared to return to sport within eight weeks of initiating treatment than those in the control group (66.2%,

95% CI 40-92.3; p< 0.001). Individuals in the intervention group who were medically cleared for return to sport had a greater improvement in the SCAT2 total score (Wilcoxon rank-sum, p=0.009) and the Dizziness Handicap Inventory Score (Wilcoxon rank-sum, p=0.019) compared to those who were not medically cleared in eight weeks.

Active Therapies in Post-Concussion Syndrome

Post-concussion syndrome has been defined as post-concussive symptoms that are present at least 30 days after a mTBI. These symptoms can vary to include physical, cognitive, emotional, and/or behavioral complaints. Currently, no evidence-based guidelines exist related to the management of patients with persistent symptoms (> 1 month) post-concussion.

Many studies have been completed evaluating the effect of physical activity on acute concussion recovery, however, not many have been completed with post-concussion syndrome. Chan et al. (2017) conducted a randomized control trial with an aim at evaluating the safety and efficacy of active rehabilitation via graded aerobic exertion versus usual care for patients with post-concussive symptoms.

Methods of this study included patients ages 12-18 who had sustained a sport-related concussion and had two or more persistent post-concussive symptoms (defined as four or more weeks post-injury). Patients were randomized into either the experimental group (active rehabilitation, n=10) or the ‘treatment as usual’ (TAU, n=9) group. Participants in both groups received care from an interdisciplinary team which consisted of a psychiatrist consultation, an occupational therapist-lead educational session on symptom management and a school consultation with a hospital-affiliated teacher who facilitated return to school. Participants in the experimental group also completed active rehabilitation with guidance of a physical therapist. Their active rehabilitation program consisted of submaximal aerobic training, light coordination,

sport-specific exercises, a home exercise program, visualization and imagery techniques. Patients were evaluated in the clinic weekly. The primary outcome measure observed was patient-reported symptoms assessed by way of the PCSS. Secondary outcome measures included health-related quality of life, Beck Depression Inventory for Youth, second edition, Pediatric Quality of Life Multidimensional Fatigue Scale, Teen Report Standard Version, BESS, and ImPACT. Adverse events were defined as significantly worsened symptoms from the previous week, a decrease in attendance in school or extracurricular activities due to symptoms, an ED visit related to post-concussive symptoms, and new injuries.

Each group had six reported adverse events. The most common adverse event was an increase in post-concussive symptoms. Of the 12 total adverse events, four were reported to the external Data and Safety Monitoring Board. All four were reviewed by the board and deemed unrelated to active rehabilitation and participation in the study. In linear mixed modeling, the active rehabilitation group showed a greater reduction of post-concussive symptoms when compared to the treatment as usual group ($p=.047$).

Kurowski et al. (2017) conducted a randomized clinical trial with the objective of reporting patient outcomes with aerobic activity versus whole body stretching for management of persistent post-concussive symptoms. Kurowski et al. (2017) hypothesized that sub-symptom aerobic activity would hasten recovery times and improve patient outcomes compared to stretching, similar to studies completed for acute post-concussive symptoms.

Adolescents between the ages of 12 and 17 who had sustained a concussion within 4 to 16 weeks with persistent symptoms were eligible to participate in the study. Thirty patients met the inclusion criteria. All participants underwent a baseline assessment that included an aerobic bike test with a recumbent stationary bike. Based on the cycling duration that was completed

prior to symptom exacerbation, a home exercise program was developed for the intervention group (n=15). Patients were given the same portable exercise bike utilized in the baseline assessment for home use and asked to complete the recommended cycling program five to six days per week at home at 80% of the duration that exacerbated symptoms during the baseline assessment. When patients in the intervention group returned for their weekly visits the baseline test was repeated and their home program was adjusted for the next week. Participants in the stretching group (n=15) were instructed on a full body stretching program and asked to complete it five to six days per week. At their weekly visits they were given a new group of stretches. All participants were asked to complete a total of 6 weeks of their respective exercises. The primary outcome measures observed were Post-Concussion Symptom Inventory (PSCI) completed by both the patient and their parents. The PCSI was evaluated pre-intervention and at weeks 2-6.

With the self-reported PCSI rating from week one to week seven, the intervention group showed a greater rate of improvement with sub-symptom aerobic training than participants in the stretching group (p=0.044). Parent reported PCSI ratings did not show statistically significant improvements in the intervention group when compared to the stretching group (p=0.68).

Evidence clearly suggests that patients recovering from an acute mTBI may have psychosocial and emotional complaints, allowing a simple conclusion that patients with prolonged recovery may also have persistent psychosocial and emotional complaints.

McCarty, Zatzick, Stein, Wang, Hilt, and Rivera (2016) conducted a randomized control trial among adolescents with persistent post-concussion symptoms. Their objective was to evaluate whether the implementation of cognitive behavioral therapy (CBT), in conjunction with a collaborative care treatment model, would reduce post-concussive symptoms to include affective symptoms of depression and anxiety. They hypothesized that patients in the

intervention group would demonstrate improved quality of life by way of reduced depression and anxiety symptoms.

Methods of this study included adolescents 11 to 17 years of age with a diagnosed sports or recreation related concussion and symptoms that were present for > 1-month post-injury. Participants were randomized into the collaborative care (intervention) group (n= 23) or usual care (control) group (n=24) by way of computer randomization developed by a study statistician. Patients in the intervention group received care to include CBT, coordination with the patient's school, and guidance via a multidisciplinary team comprised of a pediatrician and a psychiatrist. Patients in the control group initially visited a sports medicine physician and were referred to pediatric rehabilitation. Participants and their parents reported at one month, three months, and six months regarding post-concussive symptoms by way of the Health and Behavior Inventory (HBI), Patient Health Questionnaire (PHQ-9), PROMIS-PA8 (version a), Pediatric Quality of Life Inventory (PedsQL), and a Client Satisfaction Questionnaire.

Results of the study showed statistically significant improvements in patient quality of life as well as improved post-concussive symptoms in the intervention group when compared with the control group at six months ($p<.05$). Patients in the intervention group did report reduction in depressive symptoms, but when compared to those in the control group this does not appear to have reached statistical significance. There were no adverse effects reported as a result of this investigation.

Discussion

Given the increased incidence of adolescent concussions, the amount of research conducted related to the management of concussion has also greatly increased in recent years. The following

section is a discussion of the literature that is focused on the management of acute concussion and post-concussion syndrome.

In adolescents with acute concussion, what is the effect of active therapies compared to traditionally prescribed cognitive and physical rest in improvement of symptoms?

An observational study by Taubman et al. (2016) observed 95 patients diagnosed with an acute concussion. Fifty-eight patients initiated cognitive and physical rest on the day of injury and 37 patients did not initiate immediate cognitive and physical rest. The results of the study indicated a statistically significant ($p<0.05$) difference in recovery times between those who initiated immediate rest and those who did not. Those who did not initiate immediate rest showed an increased likelihood for prolonged recovery (returning to school after 30 days or longer post injury).

A prospective randomized controlled trial of adolescent patients with acute concussion by Thomas et al. (2015) enrolled patients ages 11 to 22 and implemented either five days of strict cognitive and physical rest (intervention group) or 24 to 48 hours of cognitive and physical rest (control group). Eighty-eight patients completed the study and follow-up procedures. The results of the study reported longer recovery times for patients in the intervention group as well as greater total symptom scores when compared to the control group ($p<0.03$). It is of note that the median duration of activity restriction in the intervention group was two days as opposed to the prescribed five days.

The results of the studies completed by Taubman et al. (2016) and Thomas et al. (2015) support the CDC's recommendation for immediate cognitive and physical rest following an acute concussion. The study completed by Thomas et al. (2015) is one of the only studies to date that has attempted to evaluate well-defined cognitive and physical rest duration during acute

concussion recovery. Further studies are required to definitively determine appropriate strict rest duration and may be patient dependent. Limitations of these two studies include small sample sizes, patient reporting by way of diaries and interviews, and poor patient compliance.

Lawrence et al. (2018) conducted a retrospective study to evaluate when aerobic exercise can safely and effectively be reintroduced to patient's daily activities following acute concussion. The primary outcome measure observed was full return to school and sport. The results of this study showed that patients who initiated aerobic exercise later (14 days) reduced their probability of full return to sport by a greater percentage than those who initiated aerobic exercise at three days. Similarly, patients who initiated aerobic exercise later (14 days) reduced their probability of full return to school by a greater percentage than those who initiated aerobic exercise at three days. The results suggest that three days post-injury may be an optimal time to initiate aerobic exercise in the acute concussion patient. Further studies should be completed to definitively determine optimal time to initiate aerobic exercise for maximal recovery. Limitations of this study include that it did not allow for comprehensive assessment of exercise intensity, type, and symptom response. Therefore, detailed recommendations regarding these variables cannot yet be made.

Leddy et al. (2019) hypothesized that aerobic exercise would improve patient outcomes during concussion recovery. A parallel, randomized clinical trial comparing sub-symptom aerobic exercise to sub-symptom stretching exercise was completed to test this hypothesis. Fifty-two patients comprised the aerobic exercise group and 51 comprised the stretching group. The results of this study showed a statistically significant ($p= 0.009$) difference in recovery times between the aerobic exercise group and the stretching group. The aerobic exercise group recovered in a median time of 13 days and the stretching group recovered in a median time of 17

days. The results of this study indicate that sub-symptom aerobic exercise can significantly improve patient recovery times.

The results of the studies completed by Lawrence et al. (2018) and Leddy et al. (2019) overall suggest that aerobic exercise has beneficial effects on recovery from an acute concussion, primarily by speeding recovery times. Further studies are required to determine and establish specific recommendations regarding when to initiate aerobic exercise, what type of aerobic exercise to initiate, and intensity.

Patients recovering from a mTBI often complain of dizziness, lack of balance, and nausea. Lennon et al. (2018) completed a retrospective observational study that observed the safety and efficacy of physical therapy treatment programs that had been initiated at varying times post-injury. The primary outcome measure observed was symptomology by way of the PCSI. The secondary outcome measure observed was safety by way of chronicling unplanned visits to a healthcare provider. The results of this study did not show a statistically significant difference regarding change in PSCI scores whether physical therapy was implemented at 0-20 days post-injury, 21-41 days post-injury, or >42 days post-injury ($p=0.38$). Regarding safety, seven of the 120 individuals observed had an unplanned visit to a healthcare provider within one week of a physical therapy session.

Murray et al. (2016) conducted a systematic review to evaluate the utility of vestibular rehabilitation in acute concussion management. Their search yielded >3,000 articles with 10 meeting the final criteria. All ten studies reported improvement in patient dizziness, gaze stabilization, balance, gait, and time to return to school/sport. No adverse effects to vestibular rehabilitation were found. The results suggest but do not definitively demonstrate that vestibular rehabilitation is not harmful to patients and may improve recovery. Because the outcome

measures of this systematic review did not allow for meta-analyses, there is a need for high-quality randomized control trials to definitively evaluate the effectiveness and safety of vestibular rehabilitation on patients with vestibular symptoms following a mTBI.

Schneider et al. (2014) conducted a randomized control trial with the goal of examining whether a combination of physical therapy and vestibular rehabilitation compared to physical therapy alone decreases patient recovery times. Twenty-nine individuals met the inclusion criteria and participated in the study. Fifteen participants made up the intervention group met with a physical therapist weekly and completed additional vestibular rehabilitation. Fourteen participants made up the control group who met with a physical therapist weekly and did not partake in vestibular rehabilitation. The primary outcome measure observed was the duration between initiation of treatment and clearance for return to school/sport. Secondary outcome measures observed included pain rating, balance scores, dizziness scores, motion sensitivity tests, and gait assessment. The results of this study showed a greater proportion of patients in the intervention group being cleared for return to school/sport within eight weeks of treatment than those in the control group ($p<.001$). Of the secondary outcome measures observed, only the SCAT2 and Dizziness Handicap Inventory Scores showed statistically significant improvement in the intervention group compared to the control group ($p=0.009$ and $p=0.019$, respectively).

Overall, the studies completed by Lennon et al. (2018), Murray et al. (2016), and Schneider et al (2014) suggest that vestibular rehabilitation, when used in conjunction with traditional management to include immediate cognitive and physical rest post-injury, sub-symptom stretching, and postural education improves recovery time. Further research is needed to determine optimal timing of treatment. It is of note as well that these studies included adults up to age 30.

In adolescents with post-concussion syndrome, what is the effect of active therapies compared to traditionally prescribed cognitive and physical rest in improvement of symptoms?

According to the CDC's guideline for the diagnosis and management of acute concussion, patients should achieve full recovery in 4-6 weeks (Lumba-Brown et al., 2018). The guideline states that patients with premorbid conditions such as previous mTBI, lower cognitive ability, diagnosed neurological or psychiatric disorder, and familial or social stressors, may be at risk for delayed recovery (Lumba-Brown et al., 2018). Chan et al. (2017) conducted a randomized control trial that aimed at evaluating the safety and efficacy of aerobic exertion versus usual care. The experimental group completed physical therapy, graded aerobic exercise and usual care which consisted of psychiatric evaluation, occupational therapy, and consultation with a hospital affiliated teacher who facilitated return to school. The control group only completed usual care. The primary outcome measure observed was patient-reported symptoms by way of the PCSS.

The results of the study by Chan et al. (2017) included 12 total adverse events, six in each group. In linear mixed modeling, the experimental group showed a greater reduction in PCSS scores than the control group ($p=0.47$).

Kurowski et al. (2017) conducted a randomized control trial that evaluated patient reported symptoms with aerobic activity versus whole body stretching. Aerobic activity included the use of a recumbent stationary bike. Patients in both groups completed their prescribed exercises 5-6 days per week for 6 weeks. The primary outcome measure observed was patient reported symptoms by way of the PCSI. The results of the study showed greater improvement in PSCI scores in the aerobic exercise group than the stretching group ($p=0.044$).

Overall, the studies completed by Chan et al. (2017) and Kurowski et al. (2019) suggest that sub-symptom aerobic exercise in conjunction with usual care can improve patient reported symptoms in those with prolonged recovery from a mTBI. Limitations to these studies include limited sample sizes and patient adherence to treatment recommendations in each. Future studies could implement monitoring during prescribed exercise to accommodate for this. At this time, definitive recommendations cannot be made for clinical care because of these limitations.

Patient's recovering from an acute mTBI have reported psychosocial complaints to include both anxiety and depression. These symptoms often persist if other physical symptoms persist, especially if the adolescent is absent from school and extracurricular activities. McCarty et al. (2016) conducted a randomized control trial to evaluate whether cognitive behavioral therapy in addition to school coordination and guidance via a pediatrician and a psychiatrist would demonstrate improved quality of life by way of reduced depression and anxiety symptoms. Participants either received collaborative care mentioned above or usual care that included an initial visit with a sports medicine physician and subsequent pediatric therapy (occupational and/or physical). Outcome measures observed included the Health and Behavior Inventory (HBI), Patient Health Questionnaire (PHQ-9), PROMIS-PA8 (version a), Pediatric Quality of Life Inventory (PedsQL), and a Client Satisfaction Questionnaire. The results of this study demonstrated no adverse effects to treatment in either group. Only two outcome measures reached statistical significance. For the intervention group, youth reported HBI scores improved at six months and both parent and youth quality of life reports improved at six months ($p<0.05$). Although patients in both groups demonstrated symptom reduction during the first three months of treatment, only those in the intervention group demonstrated a sustained improvement in symptoms throughout the six-month duration. The results of this study suggest that cognitive

behavioral therapy can improve perceived quality of life for patients with persistent concussion symptoms. There was not a significant reduction in anxiety or depression symptoms by way of the PHQ-9 and PROMIS-PA8, however, a greater proportion of patients in the intervention group demonstrated >50% reduction in depressive symptoms versus those in the control group. As this study did not demonstrate any adverse effects in either treatment group, it is suggested that cognitive behavioral therapy is not harmful to patients.

Limitations to the study completed by McCarty et al. (2016) include small sample sizes, limited generalizability, and heterogeneity of symptom duration. Larger, randomized clinical trials are required to make definitive recommendations for the use of a collaborative care model for patients with persistent post-concussion symptoms to include anxiety and depression.

Application to Clinical Practice

Although the CDC has published clinical practice guidelines regarding the management of acute concussion, the guidelines are quite vague. Thus, management is often left to the discretion of the patient's primary care provider and recommendations are widely debated. As the prevalence of mTBIs rise, it is imperative for the medical provider to make the most efficacious and safest recommendations regarding the management of adolescents who suffer from sports-related concussion and post-concussion syndrome.

After completing this literature review, no specific duration of immediate cognitive and physical rest following a mTBI was discovered, however, there was evidence of substantial benefit for its implementation. The evidence suggests that 24-48 hours of immediate cognitive and physical rest provides the most benefit for patients. This is in contradiction to the historically recommended prolonged cognitive and physical rest and an expansion on the CDC's guideline which recommends rest for 'several days.'

In addition, the research reviewed has shown that earlier implementation of active therapies such as aerobic exercise, physical therapy, and cognitive behavioral therapy can benefit patients recovering from a mTBI. These therapies benefit patients by way of reducing recovery times which results in sooner return to school and sport. It is important to note that for the primary care provider to implement these recommendations, they must prepare the correct referral path and incorporate other members of the healthcare team. This can include athletic trainers, physical therapists, school counselors or psychiatrists. Additional cost evaluation is warranted to assess cost versus savings and healthcare utilization associated with collaborative care.

The research regarding active therapies in the management of post-concussion syndrome is limited. Of the studies reviewed, it is suggested that active therapies can provide similar benefit to patients with persistent concussion symptoms > 1 month as with an acute mTBI. All the studies reviewed showed no adverse effects to treatment which suggests that active therapies are safe with little to no risk to patients with prolonged recovery.

Overall, further research is required to determine definitive recommendations for an acute mTBI and post-concussion syndrome management. Larger, blinded, randomized control trials are required to determine optimal duration of cognitive and physical rest, optimal timing of initiation of active therapies, optimal exercise type, intensity, frequency and duration, and finally, cost analysis.

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