Rehabilitation Utilizing Controlled Aerobic Activity in Patients With a Concussion: A Critically Appraised Topic

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Clinical Scenario: A sport-related concussion is a common injury to the brain that may cause a variety of symptoms ranging in duration and severity. The mainstay of treatment for concussion has been rest, followed by a stepwise return to activity. This recovery process may be lengthy when symptoms persist. Aerobic exercise conducted at subsymptom and submaximal intensities has been proposed as a potential intervention for symptoms following a concussion. Therefore, the purpose of this critically appraised topic is to examine the safety of varying aerobic exercise intensities in patients with a concussion. **Focused Clinical Question:** Are subsymptom and submaximal exercise programs safe when implemented in a population with a symptomatic sports-related concussion when compared with traditional rest? **Summary of Key Findings:** Four randomized controlled trials were included for critical appraisal. The 4 studies investigated supervised and controlled aerobic exercise as early as within 1 week of with a concussion; all studies conclude that exercise is safe and may be of benefit to individuals with a concussion. Two studies support the use of submaximal exercise as a therapeutic intervention for adolescents with persistent concussion symptoms. **Clinical Bottom Line:** The authors conclude that controlled exercise performed within the symptom or exertion threshold of patients with concussion is safe compared with rest. It was noted that symptom changes may occur; however, the changes did not have a negative impact on long-term recovery. This research should ease concerns about prescribing physical activity when an athlete with concussion is still experiencing lingering symptoms. While specific parameters of the activity performed have not been described in detail, the individualization of each exercise program was stressed. **Strength of Recommendation:** Grade A.

Keywords: postconcussion syndrome, mild traumatic brain injury, submaximal exercise, rest, therapeutic exercise

Clinical Scenario

An estimated 1.6 to 3.8 million concussions occur in sport and recreational activities annually.¹ A sport-related concussion (SRC) is contemporarily defined as a traumatic brain injury induced by biomechanical forces.² Symptoms of concussion are caused by the metabolic cascade, which includes excitatory neurotransmitter release, abnormal ion fluxes, increased glucose metabolism, lactic acid accumulation, elevated cerebral blood flow, energy deficit, and inflammation.³⁻⁵ These changes in the brain are responsible for the hallmark symptoms of a concussion, such as headache, nausea, loss of consciousness, and pressure in the head.

Most concussions resolve within 2 to 4 weeks, but approximately 10% to 33% of individuals have persistent symptoms for months after the initial injury.⁶⁻⁸ An associated comorbidity following concussion is postconcussion syndrome (PCS). Clinical diagnostic criteria for PCS require a history of brain injury and the presence of at least 2 symptoms for a minimum of 4 weeks.⁹ Having 3 of 8 symptoms (headache, dizziness, fatigue, irritability, insomnia, concentration problems, memory difficulty, or intolerance of stress emotion or alcohol) for at least 4 weeks has also been identified as grounds for PCS classification.¹⁰ The mainstay of treatment for an SRC, traditionally, is rest followed by a stepwise return to learn, then physical activity and, finally, return to sport. Time lost due to concussion is at least 5 days following symptom

resolution when following best practices for full return to contact sports.¹¹

Currently, prescribed rest in which patients avoid physical and cognitive activity is the most widely used intervention.² Recent research indicates that strict rest longer than 1 to 2 days following a concussion does not improve outcomes and may potentially cause an increase in symptom reporting.¹² The increase in symptom reporting, especially in athletes after prescribed rest, may be due to physical deconditioning⁶ and the development of secondary symptoms, such as fatigue and reactive depression. Exercise, in general, has benefits for body composition, skeletal health, cardiorespiratory fitness, depression, anxiety, and academic achievement,¹³ and it also improves cognition through increased cerebral blood flow, oxygen extraction, brain metabolism, and neuroplasticity.¹⁴⁻¹⁶

Aerobic exercise conducted at subsymptom and submaximal intensities has been proposed as a potential intervention for the negative effects of inactivity following a concussion.^{9,10,17} Subsymptom aerobic exercise has been defined as aerobic exercise performed at an intensity and duration that does not exacerbate postconcussion symptoms.¹⁰ The American College of Sports Medicine defines submaximal exercise as aerobic activity occurring at 85% of the age-adjusted maximum heart rate.¹⁸ These terms used by different authors often refer to similar exercise intensities, but they cannot be used interchangeably. Therefore, the purpose of this critically appraised topic is to examine the safety of varying aerobic exercise intensities in patients with a concussion. In appraising the safety of controlled aerobic activity in comparison with complete rest, clinicians will be able to determine if physical activity can be implemented in the plan of care for patients with a concussion.

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Focused Clinical Question

Are subsymptom and submaximal exercise programs safe when implemented in a population with a symptomatic SRC when compared with traditional rest?

Summary of Search, “Best Evidence” Appraised, and Key Findings

- The literature was searched for level 2b or higher quality studies that investigated the use of aerobic exercise in SRC rehabilitation.
- Four randomized controlled trials^{9,10,17,19} were included for critical appraisal.
- All 4 studies investigated supervised and controlled aerobic exercise as early as within 1 week of an SRC, and conclude that exercise is safe and may be of benefit to individuals with concussion.
- Two studies^{9,10} support the use of submaximal exercise as a therapeutic intervention for adolescents with persistent concussion symptoms.

Clinical Bottom Line

There is evidence that athletic patients engaging in controlled physical activity while recovering from an SRC can be safely included in rehabilitation without a long-term increase in symptoms. In addition, this can be done without increasing time to recovery. There is limited evidence that shows greater symptom improvement in groups that participated in controlled physical activity.

Strength of Recommendation

Based on the Centre for Evidence-Based Medicine level of evidence criteria, there is grade A evidence to support the safety of controlled aerobic exercise in rehabilitation of an SRC. The included studies are randomized controlled trials that utilized consistent, good-quality patient-rated evidence to drive their results.

Search Strategy

MeSH Terms Used to Guide Search Strategy

- Population: athlete or concussion or head injury or brain injury or mild traumatic brain injury
- Intervention: submaximal exercise or submaximal physical activity, or subsymptom exercise or subsymptom physical activity, or subthreshold exercise or subthreshold physical activity
- Comparison: rest
- Outcome: symptom increase or adverse events

Sources of Evidence Searched

- PubMed
- CINAHL
- SPORTDiscus
- MEDLINE

- Additional resources obtained via review of reference lists and hand search

Inclusion and Exclusion Criteria

Inclusion Criteria

- Athletic patient population
- Randomized controlled trials
- Limited to English language
- Published within the last 10 years

Exclusion Criteria

- No additional exclusionary criteria

Results of Search

The results of the search are detailed in Figure 1. We excluded 533 articles based on irrelevant titles. The majority of articles excluded based on the title did not have any resemblance to our PICO strategy. Most commonly, there was no reference to concussion or head injury, and/or a therapeutic intervention. Four eligible studies^{9,10,17,19} were included and evaluated by 2 individual raters and categorized as shown in Table 1. Evaluation tools available for appraisal of randomized controlled trials are the PEDro²⁰ and the Downs and Black.²¹

Figure 1 — Exclusions of search results

Table 1 Summary of Evidence Appraisal

	PEDro ²⁰	Downs and Black ²¹	Level of evidence
Chan et al ⁹	9	23	1b
Kurowski et al ¹⁰	9	23	1b
Maerlender et al ¹⁹	6	22	2b
Leddy et al ¹⁷	10	26	1b

Best Evidence

The studies described in Table 2 represent the best available evidence regarding the use of submaximal and subsymptom aerobic exercise for patients with a concussion, and they were chosen to be included in this critically appraised topic.

Implications for Practice, Education, and Future Research

All 4 studies investigated the use of aerobic exercise in patients who had sustained an SRC. There were no adverse medical events related to study procedures in any of the included studies. In the

Table 2 Summary of Included Studies

	Chan et al ⁹	Kurowski et al ¹⁰	Leddy et al ¹⁷	Maerlender et al ¹⁹
Setting	Outpatient concussion clinic	Outpatient research clinic	University sports medicine centers	Athletic training facility
Population	19 female participants who sustained an SRC at least 4 wk postinjury with 2 or more persistent PCS symptoms, mean age: 15.5 (1.47) y	32 adolescents with at least 3/8 persistent PCS symptoms lasting at least 4 wks, mean age: treatment 15 (1.36) y, control 15.5 (1.8) y, sex: 15 males and 17 females	54 adolescents identified within 1–10 d of an SRC concussion, mean age: treatment 15.19 (1.45) y, control 15.63 (1.36) y, sex: 37 males and 17 females	28 college athletes with concussion; 8 males and 20 females
Intervention	<i>Treatment:</i> active rehabilitation program described by Gagnon et al ²² with 4 components: submaximal aerobic training, light coordination and sports-specific exercise, visualization and imagery techniques, and home exercise program all administered according to a written manual, initially with physiotherapists, then transitioned to home program <i>Control:</i> education by occupational therapist, school consultation, and psychiatrist consultation	<i>Treatment:</i> 6-wk aerobic training program, based on aerobic bike test individually tailored subsymptom exacerbation home exercise training program was developed, the program was completed 5–6 d/wk at home at 80% of the duration that exacerbated symptoms during the interval and assessment visits, with weekly visits aerobic bike test was repeated, and the home program was adjusted for the following week <i>Control:</i> full-body stretching home program, 5–6 d/wk	<i>Treatment:</i> BCTT, starting speed was 3.2–3.6 depending on subject's height at a 0% incline. After each minute, the incline was increased by 1° until the subject could not continue either due to symptom exacerbation (increase of 3 or more points or appearance of a new symptom) or fatigue. Heart rate, rating of perceived exertion, and symptoms were measured each minute. The test was stopped at rate of perceived exertion ≥17 <i>Control:</i> standard of care	<i>Treatment:</i> stationary bicycle at mild–moderate (Borg rating of perceived exertion 0–6) for 20 min <i>Control:</i> no systematic exertion beyond the normal activities required for school
Main outcome measures	PCSS rating measured 8 times over the course of 6 wk on the phone with blinded assessors and in clinic symptom exacerbation	Self-rated PCSI and primary caregiver PCSI ratings	PCSS reported daily online and days to recovery	Number of days to recovery defined by time when symptoms, balance, and test scores returned to baseline
Main findings	Adverse events were no more common in participants receiving active rehabilitation protocol, and none of the adverse events reviewed by data and safety monitoring committee were ruled causally related to intervention. While both treatment and control groups saw significant improvement, the treatment effect on the PCSS was found statistically significant.	There was a significant group by time interaction for self-rated PCSI but was found nonsignificant in terms of primary caregiver PCSI ratings. Post hoc analysis reveals a faster rate of improvement in PCSI ratings in treatment group.	Symptom score at visit one and group were not significantly associated with days to recovery. Symptom scores did significantly decrease over time, but were not significantly associated with group assignment. Heart rate threshold was found to be significantly associated with days to recovery, and a lower threshold at visit one was strongly associated with prolonged recovery time.	First-day symptom increase was not related to recovery time, and the median number of days to recover was not different by group. Though there was a significant variance in recovery time with more activity increasing recovery time.
Conclusions	These data give support that closely monitored active rehabilitation programs involving controlled subsymptom threshold exercise for adults and adolescent with persistent symptoms after concussion may be of benefit and decrease concerns about prescribing increased physical activity for youth with ongoing PCS symptoms.	A greater rate of improvement was found in the subsymptom aerobic training group when compared with the control, especially at 4 wk of intervention. The subsymptom exacerbation aerobic training program is potentially beneficial compared with the full-body stretching program. However, since both groups did improve, even minimal activity may be beneficial.	These data show that exercise tolerance testing is safe in the acute period following an SRC and can identify adolescents who will be slow to recover. The results of the BCTT should be used to prescribe individualized low-level subsymptom threshold aerobic exercise as a treatment.	Moderate physical activity did not have a significant effect on time to recovery. More time spent engaging in vigorous activity was related to increased time to recovery.

Abbreviations: BCTT, Buffalo Concussion Treadmill Test; PCS, postconcussion syndrome; PCSI, Postconcussion Symptom Inventory; PCSS, Postconcussion Symptom Scale; SRC, sport-related concussion.

event of a symptom exacerbation during procedures, all symptoms resolved and did not have a negative impact on overall recovery.^{9,19} Two of the studies^{17,19} examined acute management of concussion symptoms. Leddy et al¹⁷ reported that testing exercise tolerance using the Buffalo Concussion Treadmill Test (BCTT) within the 10-day acute period following a concussion did not have a significant effect on symptom score within 24 hours compared with controls, nor did it delay recovery or illicit a long-term symptom increase. In addition, they reported that individuals who experienced prolonged symptom recovery had a lower heart rate threshold compared with controls for symptom exacerbation. This finding may indicate that the BCTT can not only be safely administered acutely after an SRC, but it may also have a level of prognostic utility for clinicians. While practitioners assess SRCs with clinical exam, as well as detailing the symptom duration and severity, symptoms might not be indicative of long-term recovery.¹¹

Maerlender et al¹⁹ observed the effect of controlled aerobic exercise programs on days to recovery in college-aged participants. They found no difference in median days to recovery between patients who followed “standard concussion recovery recommendations” and those who participated in exercise groups. They also reported exercise-induced symptom provocation on the first day of activity was not associated with increased recovery time.¹⁹ While an additional analysis of data collected through a wearable activity tracker showed that an increased amount of daily vigorous physical activity was associated with hindered recovery time, the authors concluded that moderate physical exertion was a benign factor in the recovery process.¹⁹ These 2 studies^{17,19} show that mild to moderate aerobic exercise did not have a negative effect on overall recovery in these samples of young individuals. Sports medicine teams can use these conclusions to develop evidence-based protocols for acute SRC management.

The other 2 studies^{9,10} focused on chronic symptom resolution by applying aerobic exercise interventions to individuals with PCS. Both studies investigated participants who had experienced symptoms for at least 4 weeks. Symptoms were measured via the Postconcussion Symptom Scale⁹ and the self-rated Postconcussion Symptom Inventory.¹⁰ Both studies found a significantly greater rate of improvement in those who participated in controlled aerobic training when compared with rest regardless of the outcome measure. Both studies acknowledged that the control group did improve, but not as quickly as the exercise group; the studies reported medium effect sizes of 0.51¹⁰ and 0.55.⁹ Clinicians should note that these observations suggest that controlled aerobic activity may be an effective method for improving symptoms in cases of PCS.

These 4 studies give evidence to support the safety of prescribing controlled subsymptom or submaximal physical activity in individuals with concussion. This information should be used to develop high-quality studies to investigate the efficacy of exercise as a treatment. To gain more support for efficacy of controlled aerobic exercise, further research needs to focus on determining the proper onset, mode, duration, and intensity of aerobic exercise for the purpose of decreasing SRC recovery time. Predictors to determine which patients are most likely to benefit from submaximal and subsymptom interventions should also be developed for the clinical setting.

Clinical Recommendation

We conclude that controlled exercise performed within the symptom or exertion threshold of patients with concussion is safe when

compared with rest. It was noted that brief symptom increases may occur, but that it did not have a negative impact on long-term recovery. This research should ease concerns regarding prescribing physical activity when an athlete with concussion is still experiencing symptoms. In fact, research cited in this study indicates controlled aerobic exercise, such as the BCTT, does no harm when administered postinjury. The BCTT is a progressive increase in treadmill incline while maintaining walking speed until symptom exacerbation or fatigue.¹⁷ While the other included studies did not describe the parameters of the activity performed in detail, the specific individualization of each exercise program was stressed. It is unclear in the literature whether using a subsymptom or submaximal threshold is more advantageous when providing a controlled aerobic exercise program. While these methods can yield similar protocols, more research is needed to determine which is the most effective in a clinical setting.

Reducing time lost from an SRC safely and preventing PCS are the primary uses of these interventions. Giving athletic individuals the permission to become more active helps counter maladaptive illnesses, such as reactive depression and posttraumatic stress disorder.²³ Reintegration into social and recreational activities can counter a number of mental and physical symptoms associated with removal from self-validating activities, in addition to the benefits of exercise.^{23,24} With more research, the efficacy of aerobic exercise prescription in individuals with concussion can be clearly defined. While it is found to be safe, until this literature is expanded, it will be difficult for sports medicine teams to integrate exercise following brain injury into clinical practice due to the lack of understanding regarding the proper methods of the submaximal and subsymptom exercise. These studies^{9,10,17,19} were high quality and can be used as a foundation for the design of future research projects with larger sample sizes that can build upon this body of literature.

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