Early Controlled Exercise and Timing of Treatment Following Concussion: A Critically Appraised Topic

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Clinical Scenario: Recent systematic reviews have shown that extended rest may not be beneficial to patients following concussion. Furthermore, recent evidence has shown that patient with postconcussion syndrome benefit from an active rehabilitation program. There is currently a gap between the ability to draw conclusions to the use of aerobic exercise during the early stages of recovery along with the safety of these programs. **Clinical Question:** Following a concussion, does early controlled aerobic exercise, compared with either usual care or delayed exercise, improve recovery as defined by symptom duration and severity? **Summary of Key Findings:** After a thorough literature search, 5 studies relevant to the clinical question were selected. Of the 5 studies, 1 study was a randomized control trial, 2 studies were pilot randomized controlled trials, and 2 studies were retrospective. All 5 studies showed that implementing controlled aerobic exercise did not have an adverse effect on recovery. One study showed early aerobic exercise had a quicker return to school, and another showed a 2-day decrease in symptom duration. **Clinical Bottom Line:** There is sufficient evidence to suggest that early controlled aerobic exercise is safe following a concussion. Although early aerobic exercise may not always result in a decrease in symptom intensity and duration, it may help to improve the psychological state resulting from the social isolation of missing practices and school along with the cessation of exercise. Although treatments continue to be a major area of research following concussion, management should still consist of an interdisciplinary approach to individualized patient care. **Strength of Recommendation:** There is grade B evidence to support early controlled aerobic exercise may reduce the duration of symptoms following recovery while having little to no adverse events.

Keywords: brain concussion, rehabilitation, exercise, running

Clinical Scenario

The fifth international conference on concussion in sport recommends integrating supervised aerobic exercise early in the treatment phase and reducing periods of rest to only 24 to 48 hours after injury.¹ Previous reasoning behind rest was that it reduced the risk for subsequent concussion² and reduced potential stresses on the brain to promote recovery.³ However, recent systematic reviews^{4,5} determined that the extended rest may not be beneficial to patients, and moderate activity levels and early activity may help to decrease the risk of postconcussion syndrome and improve symptom duration.⁶ Furthermore, recent statements have proposed a framework for more active treatments targeting specific clusters of symptoms following concussion to decrease comorbidities and day-to-day symptoms.⁷⁻⁹

Current literature has noted the potential effectiveness of treatments following concussion; however, most of this literature has occurred in patients with postconcussion syndrome.¹⁰ Those patients who undergo a multimodal treatment protocol (aerobic exercise, imagery, agility exercises, and balance exercises)^{11,12} or perform aerobic exercise alone have shown improvement compared with usual care and rest.¹³ There is currently a gap in the literature as moderate activity have been shown to be beneficial within the first few weeks following injury,⁵ although the treatment literature has only examined patients with symptoms for more than 4 weeks.¹⁰ Therefore, there is limited evidence to currently support

or refute the claim of early timing of active therapy following concussion and its potential benefits.

Clinical Question

Following a concussion, does early controlled aerobic exercise, compared with either usual care or delayed exercise, improve recovery as defined by symptom duration and severity?

Summary of Search, Best Evidence Appraised, and Key Findings

- Literature was searched for studies with level 3 evidence or higher that implemented early controlled aerobic exercise in the early phases of concussion management compared with usual care, rest during the early stage of recovery.
- The literature search returned 12 studies related to the clinical question; 5 studies met the inclusion criteria.
- One study was a randomized controlled trial showing aerobic exercise compared to a stretching routine resulted in a 2-day decrease in symptoms.¹⁴
- One article¹⁵ demonstrated that initiating aerobic exercise had a positive effect on returning to school/work and sport sooner rather than delayed exercise.
- All 5 articles¹⁴⁻¹⁸ demonstrated that implementing early controlled aerobic exercise did not have a detrimental effect on recovery.
- One article¹⁷ demonstrated that although the early implementation of controlled aerobic exercise resulted in temporary increases in symptoms, it did not lengthen the overall duration of symptoms and the number of days to return-to-play.

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- Four articles investigated early controlled aerobic exercise as a treatment,^{16–18} whereas 1 article¹⁸ investigated aerobic exercise as part of a multimodal treatment plan that also included manual therapy, strengthening activities, and ocular/vestibular exercise.

Clinical Bottom Line

There is sufficient evidence to suggest early controlled aerobic exercise is safe following a concussion but may not always be effective at reducing symptom intensity and duration. Although early exercise may help to reduce symptoms, this may not always lead to returning to play or sport in a shorter period. However, early aerobic exercise could potentially create a more positive experience for the patient by decreasing the affective symptoms potentially associated by being removed from sports participation along with isolation from peers. Furthermore, although early controlled aerobic exercise may be utilized as a treatment, each study had different treatment parameters (eg, duration and intensity) making it difficult to determine the optimal aerobic exercise protocol. Finally, although treatments continue to be on the forefront of concussion research and clinical practice, management should still include an interdisciplinary approach to individualized patient care.

Strength of Recommendation

There is grade B evidence to demonstrate early controlled aerobic exercise, either alone or in combination with a multimodal treatment plan, may reduce the duration of symptoms following recovery and appears to cause little to no adverse events.

Search Strategy

Terms Used to Guide Search Strategy

- Patient/Client Group: concussion, mild traumatic brain injury
- Intervention (or Assessment): treatment, rehabilitation, aerobic exercise, and exercise
- Comparison: AND usual care AND rest
- Outcome(s): symptom, recovery, and duration

Sources of Evidence Searched

- The Cochrane Library
- CINAHL
- PubMed
- SPORTDiscus
- Hand searches was also performed

Inclusion and Exclusion Criteria

Inclusion Criteria

- Studies that examined implementation of early controlled aerobic exercise in recovery compared with usual care.
- Studies that examined the initiating of early controlled aerobic exercise in recovery and/or at various time points following the onset of a concussion.
- Studies utilizing interventions such as early controlled aerobic exercise, alone or part of a multimodal treatment, in the early weeks after injury (eg, <4 wk).

Exclusion Criteria

- Studies that investigated generic physical activity levels as a factor to recovery
- Studies that were published >10 years ago
- Studies that were below level 3 evidence
- Systematic reviews and abstracts
- Studies that only included 1 gender

Results of Search

Five relevant studies were located and categorized as shown in Table 1 (based on Levels of Evidence, Centre for Evidence Based Medicine, 2011).

Best Evidence

Table 2 describes the articles identified as best evidence and included for this critically appraised topic. The included studies were selected because they were considered level 3 evidence or higher and investigated the initiation of treatment/rehabilitation and compared early aerobic exercise with usual care.

Implications for Practice, Education, and Future Research

Currently, the fifth international conference on concussion in sport consensus statement encourages early treatment, such as early controlled aerobic exercise, following the first 48 hours of rest.¹ Although there has been a growing amount of evidence for the effectiveness of controlled aerobic exercise to reduce persistent symptoms, the majority of included studies focused on patient-initiated activity or whether they followed recommendations rather than clinician programmed exercise or treatment.⁵ Based upon 2 articles included in this review, early controlled aerobic exercise initiated within 3 to 11 days postconcussion is safe but may not be effective at decreasing symptom duration and overall recovery.^{17,18} The other 3 studies demonstrated early controlled aerobic exercise from 3 to 6 days postinjury had a positive effect,^{14–16} meaning the earlier one started exercise the quicker the symptom resolution within the first 2 weeks. These findings may encourage a shift in current rehabilitation techniques from a conservative, rest-centered approach to a more active and progressive approach. Furthermore, an additional study not included in this synthesis due to its lower level of evidence,¹⁹ described a series of cases in which patients who underwent an active rehabilitation program, consisting of up

Table 1 Summary of Study Designs of Articles Retrieved

Level of evidence	Study design	Number located	Author (year)
2	Randomized controlled trial	1	Leddy et al ¹⁴ (2019)
2	Pilot randomized controlled trial	2	Micay et al ¹⁶ (2018) Maerlender et al ¹⁷ (2015)
3	Retrospective cohort	2	Lennon et al ¹⁸ (2018) Lawrence et al ¹⁵ (2018)

Table 2 Characteristics of Included Studies

Study design	Lawrence et al ¹⁵ (2018) Retrospective Cohort	Leddy et al ¹⁴ (2019) Randomized Controlled Trial	Lennon et al ¹⁸ (2018) Retrospective Cohort
Participants	253 acute concussions (148 males and 105 females) ranging from 15 to 20 y old with a mean age of 17 y were included in this study. Inclusion criteria: (1) "acute" concussion, within 14 d of initial injury. All sports and skill level were included. Exclusion criteria: (1) Injury occurred during the recovery of a previous concussion or (2) a secondary concussive event occurred during the recovery of the index injury.	Male and female adolescent athletes (13–18 y old). Total of 103 patients (48 females and 55 males). Mean age was 15.3 (1.7) y. Inclusion criteria: presenting within 10 d from sport-related concussion and diagnosed with a concussion according to international concussion in sport group criteria. Exclusion criteria: (1) evidence of focal neurologic deficit; (2) inability to exercise due to other injury such as orthopedic, cervical pathologies, diabetes, or other known disease; (3) increased cardiac risk; (4) history of moderate to severe traumatic brain injury Glasgow Coma Scale <12; (5) comorbidities such as learning disorder, depression, anxiety, 3 prior concussions; (6) sustaining another head injury during period; (7) symptom score less than 5 point on intake; (8) inability to exercise to exhaustion without symptom exacerbation on first visit; and (9) limited English proficiency.	120 participants ranging from 12 to 21 with a mean age of 14.77 y. They were split into 3 groups based on when they began intervention postconcussion: early intervention (0–20 d), middle intervention (21–41 d), and late intervention (42 d or more). Inclusion criteria: (1) a physician-verified medical diagnosis of concussion and (2) documentation of a formal referral for outpatient impairment-based PT interventions with the episode of care terminating prior to January 31, 2016. Exclusion criteria: (1) younger than 12 y of age at the time of the initial PT evaluation, (2) no history of a medical condition that mimics the signs and symptoms of prolonged concussion symptoms (eg, history of chronic headaches, depression, cardiovascular conditions), (3) no data available beyond the initial PT visit, (4) incomplete data for the initial visit symptom score or final visit symptom score, and (5) insufficient documentation or evidence of poor adherence with the PT assessment and intervention protocols.
Intervention investigated	The start time for aerobic exercise for all concussion injuries was through the use of standardized reporting concussion forms. Self-initiated aerobic exercise was defined as jogging, running, swimming, cycling, or utilization of stationary aerobic equipment. Physician prescribed exercise consisted of stationary bike protocols: 15 min at 100–130 bpm, 30 min at 100–120 bpm, 30 min at 140 bpm, sprint interval for 1 min every 5 min of a 30-min duration. Time at which the prescribed exercise was initiated, as opposed to prescribed, was used to define the time to exposure. Day 1 for the time to initiation of aerobic exercise was defined as within 24 h of the time of injury and failure to be removed from play was not coded as initiating aerobic exercise.	Participants were randomized to 1 of 2 groups either aerobic exercise or stretching group. No interventions were initiated prior to 48 h from injury. The aerobic EXG consisted each day of stationary bike or treadmill at home or in gym under supervision at prescribed target heart rate while wearing Bluetooth heart rate monitor. The prescription was calculated as 80% of the HR achieved at symptom exacerbation on the BCTT at the first visit. Participants were told to stop if symptoms increased by 2 or more points from previous symptom level, and new target rate was determined by weekly clinic BCTT performance as long as there were symptomatic. Stretching group was provided a booklet containing a gentle, whole body, progressive stretching program that would not considerable elevate HR for 20 min a day. The stretches were advanced each week.	Patients were evaluated and treated by 1 of 32 licensed physical therapists, who were trained to treat patients with concussions and had extensive experience working with children with concussions. Each physical therapist was given the latitude to determine which tests and interventions were clinically appropriate and safe to be administered with each patient but was encouraged to follow a general set of care guidelines. Recommended evaluation of the cervical included: musculoskeletal evaluation of the cervical spine, oculomotor and vestibular assessments, and physiologic/cardiovascular assessment along with corresponding treatment/guidelines (neck pain and cervicogenic headache).
Outcome measure(s)	Main outcomes evaluated for all participants were time (days from injury) to full return to (1) aerobic exercise, (2) sport, and (3) school or work (school/work). The outcomes of interest were defined as the time to (1) full return as assessed by the sports physician, or (2) physician clearance for full return. Physician determination of full return to a functional domain is individualized and relies on a combination of symptom state, current and premorbid baseline function, and objective assessments.	Main outcome was days to recovery since date of injury. The BCTT results were also considered independently and symptom resolution was defined as reporting a symptom severity score of 7 points or fewer on the postconcussion symptom scale for at least 3 consecutive days. Secondary outcome measures were the proportion of participants with delayed recovery, >30 d.	(1) Total symptom severity score on the PCSS. (2) To evaluate the safety of PT interventions provided, each patient's medical record was evaluated for any occurrences of unplanned visits to a health care provider, urgent care center, or hospital emergency department.

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Table 2 (continued)

Study design	Lawrence et al ¹⁵ (2018) Retrospective Cohort	Leddy et al ¹⁴ (2019) Randomized Controlled Trial	Lennon et al ¹⁸ (2018) Retrospective Cohort
Main findings	Initiating aerobic exercise 3, 5, 7, and 14 d postinjury was associated with a respective 36.5% (HR, 0.63; 95% CI, 0.53–0.760), 59.5% (HR, 0.41; 95% CI, 0.28–0.58), 73.2% (HR, 0.27; 95% CI, 0.16–0.45), and 88.9% (HR, 0.11; 95% CI, 0.06–0.22) increased probability of faster return to sport ($P < .001$). Initiating aerobic exercise on 3, 5, 7, and 14 d postinjury was associated with a respective 45.9% (HR, 0.54; 95% CI, 0.44–0.66), 70.5% (HR, 0.29; 95% CI, 0.20–0.44), 83.1% (HR, 0.17; 95% CI, 0.10–0.30), and 94.7% (HR, 0.05; 95% CI, 0.03–0.11) reduced probability of a slower recovery to school/work compared with initiating aerobic exercise within 1-d postinjury ($P < .001$).	There was no significant difference in compliance in daily symptom reporting between groups ($P = .16$). Aerobic exercise participants, recovered in a median of 13 d (IQR, 20–18.5 d), were as stretching group recovered in 17 d (IQR, 13–23 d). The aerobic EXG recovered significantly faster than the stretching group ($z = 2.82, P = .01$). The delayed recovery was higher in the stretching group ($n = 7$; median IQR 58 [36–62] d) compared with the aerobic EXG ($n = 2$; median IQR [46–54] d) but did not reach significant ($P = .08$).	Intervention cohorts did not statistically differ with regard to their initial ($P = .50$), final ($P = .13$), or change in ($P = .38$) PCSS scores. All 3 cohorts demonstrated an overall reduction in PCSS values. 13 patients (10.8%) reported higher PCSS values (ie, higher symptom burden) at the final visit compared with the initial visit. Out of the 120 records included, 7 (5.8%) individuals had an unplanned visit to a health care provider for symptom exacerbation within 1 wk of a PT session.
Level of evidence	3	1	3
Validity score (if applicable)	N/A	N/A	N/A
Conclusion	Initiating aerobic exercise at 3 d was associated with a decrease risk for persistent symptoms compared with current standards of rest. Overall, aerobic exercise was associated with improved time with regard to return to school/work.	Subsymptom threshold aerobic exercise safely speeds up symptom resolution in adolescents following concussion. However, this may not relate to return to sport, as they did not record the date the participants returned to their respective activity. Although there was a trend in exercise reducing the incidence of delayed recovery, this was not clinically different from the stretching group.	Both groups had reduced symptoms postintervention, though a conclusion cannot be made on which is more effective. However, the low rate of adverse events indicates that a randomized controlled pilot study multimodal, impairment-based treatment is likely safe, regardless of the timing. Treatment is safe but may not be more effective than the current standard of care.
Study design	Maerlender et al ¹⁷ (2015) Pilot Randomized Controlled Trial	Micay et al ¹⁶ (2018) Pilot Randomized Controlled Trial	
Participants	18 college-aged participants assigned to either a standard care group ($N = 15$) or exertion group ($n = 13$). 71% were female participants. Inclusion criteria: (1) college-aged athletes, (2) recently suffered a concussion and diagnosed by athletic trainer. Exclusion criteria: (1) injury severity was judged as not preventing them from participating in the exercise protocol.	15 adolescent male athletes, aged 14–18 y old with physician diagnosed sport-related concussion who were symptomatic 5 d postinjury. Participants randomized into usual care (UCG) and aerobic EXG. Inclusion criteria: (1) parental consent if aged less than 16 y and (2) symptom score of >5 on the PCSS. Exclusion criteria: not specified.	
Intervention investigated	Exertion protocol consisted of riding a Schwinn Aridyne stationary bicycle at perceived exertion level of mild to moderate (0–6 on RPE scale). Standard care athletes were instructed to not engage in systematic exertion beyond normal activities required for school (ie, walking, studying, etc).	The UCG were directed through the existing 6-stage progression of activity by their attending sport-medicine physician. This similarly reflected the Berlin 2016 guidelines. The UCG was assessed at weeks 1, 2, 3, and 4 postinjury for RTP status and PCSS. All progress was determined by sports medicine physicians. The EXG was directed through a standardized aerobic exercise intervention that started on day 6 postinjury. The first stage corresponded to 50% of participant's age-predicted maximal heart rate for 10 min followed by 20 min duration with 5% increases in heart rate until they reached 70%. EXG participants were also participating in a 6-stage activity progression protocol monitored by their physician. Participants were assessed at weeks 1, 2, 3, and 4 for RTP status and PCSS.	

(continued)

Table 2 (continued)

Study design	Maerlender et al ¹⁷ (2015) Pilot Randomized Controlled Trial	Micay et al ¹⁶ (2018) Pilot Randomized Controlled Trial
Outcome measure(s)	(1) Actigraph data: for activity levels. (2) Neurocognitive test (ImPACT), Borg RPE scale, symptoms. (3) Time to recovery (days). Symptoms were measured preexercise and postexercise, and the neurocognitive test we used to determine the influence of exercise on further recovery.	The aerobic exercise intervention was determined to be feasible if (1) symptoms did not become exacerbated during or immediately after exercise compared with preexercise levels and (2) EXG participants were able to complete the entire aerobic exercise intervention. The efficacy of the intervention was evaluated by symptom status and time to medical clearance (in days) compared with usual care.
Main findings	Median number of days to recovery was not significant between exertion group and standard care group ($P = .70$). No significant difference in prolonged recover between groups ($P = .70$). More bike rides resulted in some level of symptom change vs no change ($P = .03$). First day symptom increase following bike ride was not related to recovery time ($R^2 = .12$, $P = .25$). Average amount of daily vigorous exertion accounted for small variance in recovery time, thus more activity increased recovery time (mean = 7.02, SD = 2.18, $R^2 = .18$, $P = .039$).	A significant association identified between time to medical clearance and acute symptom severity (ie, PCSS symptom severity at day 5 postinjury), which yielded a beta coefficient score of 0.57 ($P = .04$). Resolution of symptom severity was noticeably more significant in the EXG compared with the UCG, particularly between weeks 1 and 3 (15.8 [1.9] vs 6.7 [4.1] points, respectively) and weeks 1 and 4 (18.8 [4.9] points vs 10.0 [6.1] points, respectively) postinjury.
Level of evidence	3	3
Validity score (if applicable)	N/A	N/A
Conclusion	The study suggests although acute programmed physical exertion may result in temporary increases in symptoms, they do not affect recovery. Furthermore, exercise following a concussion is safe and should be monitored by an appropriate clinician.	Postacute structured aerobic exercise, beginning on day 6 postinjury appears to be both safe and feasible to administer to symptomatic adolescent patients with sport-related concussion. Structured AE appears to be associated with faster resolution of symptom severity compared with “usual care.”

Note. BCTT = Buffalo Concussion Treadmill Test; IQR = interquartile range; HR = hazard ratio; RPE = rating of perceived exertion; PT = physical therapy; UCG = usual care group; RTP = return to play; PCSS = postconcussion symptom score; EXG = exercise group; CI = confidence interval.

to 30 minutes of daily activity, before 2 weeks postinjury had a better improvement in symptom intensity and duration than those starting the program at 6 weeks or later.

Recent qualitative studies examining recovery have described the removal of patients following concussion from their daily social interactions along with the sudden decrease in aerobic fitness may negatively affect their quality of life.^{20,21} Early aerobic exercise, even while the patient is symptomatic, may help to decrease some of these sudden changes while improving the overall mood state of the individual²² and potentially reducing the risk of prolonged recovery.¹⁴ However, clinician supervision is essential in early controlled aerobic exercise to ensure the initiation of activity does not exacerbate symptoms and patients participate at a subsymptom threshold.¹⁷ The temporary increases in symptoms that may appear during or immediately following early aerobic exercise does not seem to hinder overall recovery timelines. Although the available research is not able to give definitive recommendations to change the standard of concussion management, the lack of adverse effects associated with early controlled exercises following a concussion is promising. To maintain safe exposure to exercise, clinicians should monitor patients and administer a progressive aerobic exercise program through appropriate supervision and documentation.

The use of bikes and treadmills were mostly used as the form of exercise across all studies. However, each study utilized slightly different methods to determine the appropriate intensity and duration for patients. Only one study¹⁴ utilized an exertional test (ie, Buffalo Concussion Treadmill Test) to determine specific heart rate ranges for each individual patient. Other studies utilized a general prescription of exercise based upon heart rate for all patients with increasing intensity at various stages, such as 15 minutes at 100 to 130 bpm progressing to 30 minutes at 100 to 120 bpm,¹⁵ whereas another study used an age-derived formula to prescribe a heart rate level.¹⁶ With each study prescribing varying intensities and frequencies of aerobic exercise, it is hard to determine the optimal level of early controlled aerobic exercise following a concussion. However, the collective literature seems to describe an exercise protocol beginning at a workload of 100 to 130 bpm for a duration of 10 to 30 minutes, followed by a progression of increasing intensity and duration that remains below symptom thresholds. Overall, each patient should be supervised and treated with individualized care to provide treatment that is safe, timely, and effective.

Although most studies investigated programmed exercise as a sole treatment, 1 study examined multiple treatments consisting of impairment-targeted interventions,¹⁸ which more likely reflects what clinicians should do in practice. Utilizing this approach may be beneficial as symptoms experienced following a concussion are often clustered into concussion profiles or subtypes, including vestibular, ocular, migraine-headache, mood, or cervicogenic and each profile may require a specific type of treatment.⁸ The aerobic exercise program utilized in conjunction with the targeted treatments in this study was similar to the studies using only aerobic exercise and included symptom limited aerobic activity that increased in intensity over treatment sessions. Future research should determine if the addition of symptom targeted interventions in conjunction with early aerobic exercise has a more beneficial effect on symptom recovery.

Although some studies included in this critically appraised topic did not show a decreases in symptoms,^{17,18} early aerobic exercise appears to have a low risk for adverse events.²³ Furthermore, most patients demonstrate a desire to want to perform activity and be socially involved with their peers, school, and

sport.²⁴ After their recovery, patients identified that aerobic exercise and education regarding energy maintenance were the most useful and engaging parts of a concussion rehabilitation program.²⁵ Therefore, even though early aerobic exercise may not always be better than usual care, it may increase the psychological state of the patient and improve the experiences during recovery. Future studies should continue to examine the role of treatment from both the patient's experience and recovery and from the clinician's perspective of comfort and resource utilization.

In conclusion, early treatment is safe with little risk for adverse event and may be effective at reducing symptoms following a concussion during the earlier stages, while providing psychosocial benefits to the patient. Although early aerobic exercise may be prudent, individualized clinical decision making considering each patients unique traits should be considered to ensure patient safety and monitor recovery. Furthermore, it is important to consider the potential positive effects each patient may have along with how it affects their experience and psychosomatic nature. Future research should continue to determine the best treatment following injury and correct dosage with regard to duration and frequency regarding early controlled aerobic exercise. This critically appraised topic should be reviewed in 2 years to update the current recommendation with newly available evidence.

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