Subsymptomatic Aerobic Exercise for Patients With Postconcussion Syndrome: A Critically Appraised Topic

Katrina G. Ritter, Matthew J. Hussey, and Tamara C. Valovich McLeod

Clinical Scenario: Patients who experience prolonged concussion symptoms can be diagnosed with postconcussion syndrome (PCS) when those symptoms persist longer than 4 weeks. Aerobic exercise protocols have been shown to be effective in improving physical and mental aspects of health. Emerging research suggests that aerobic exercise may be useful as a treatment for PCS, where exercise allows patients to feel less isolated and more active during the recovery process. Clinical Question: Is aerobic exercise more beneficial in reducing symptoms than current standard care in patients with prolonged symptoms or PCS lasting longer than 4 weeks? Summary of Key Findings: After a thorough literature search, 4 studies relevant to the clinical question were selected. Of the 4 studies, 1 study was a randomized control trial and 3 studies were case series. All 4 studies investigated aerobic exercise protocol as treatment for PCS. Three studies demonstrated a greater rate of symptom improvement from baseline assessment to follow-up after a controlled subsymptomatic aerobic exercise program. One study showed a decrease in symptoms in the aerobic exercise group compared with the full-body stretching group. Clinical Bottom Line: There is moderate evidence to support subsymptomatic aerobic exercise as a treatment of PCS; therefore, it should be considered as a clinical option for reducing PCS and prolonged concussion symptoms. A previously validated protocol, such as the Buffalo Concussion Treadmill test, Balke protocol, or rating of perceived exertion, as mentioned in this critically appraised topic, should be used to measure baseline values and treatment progression. Strength of Recommendation: Level C evidence exists that the aerobic exercise protocol is more effective than the current standard of care in treating PCS.

Keywords: rehabilitation, brain concussion, exercise training, return to play, persistent symptoms

Clinical Scenario

It is estimated that approximately 1.1 to 1.9 million sport-related concussions occur in patients 18 years or younger in the United States annually.1 Most adult patients who suffer from a concussion experience full relief from symptoms within 7 to 10 days of injury.2 However, approximately 10% to 20% of patients who sustain concussions experience symptoms that persist beyond this point. Patients who suffer from 3 or more symptoms, including headache, dizziness, fatigue, irritability, insomnia, concentration problems, or memory difficulty, for 4 or more weeks are diagnosed with postconcussion syndrome (PCS).3 Current recommendations for the treatment of concussions and PCS include physical and cognitive rest; however, this recommendation is vague, lacks evidence,4 and leaves a large degree of decision making up to the individual clinician. For a long time, it was believed that total rest until symptom resolution was the best practice for management of concussion and associated conditions. In recent years, there has been a shift in clinical treatment approaches that bring a more active recovery to the forefront of concussion management.5–8 These treatments vary based on the types of symptoms and deficits that persist after concussion. Aerobic exercise protocols have been identified as a potentially beneficial treatment for individuals with persistent symptoms who are exacerbated by exertion. Prior research has used aerobic protocols to establish subsymptom baseline values.8 Patients are subjected to an initial aerobic protocol to establish the baseline symptomatic threshold. In the standard Balke Treadmill Concussion test, the baseline is determined by the patient reporting symptoms or unable to achieve full incline.5,9 In the studies included, there were minor variations in time and intensity utilized in the protocols.10–13 These values are then used to develop active rehabilitation protocols for patients after concussion in which they complete aerobic activity at a subsymptomatic threshold of between 60% and 80% of the baseline threshold.10–13

Clinical Question

Is aerobic exercise more beneficial in reducing symptoms than current standard care in patients with prolonged symptoms or PCS lasting longer than 4 weeks?

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

• The literature was searched for studies that investigated whether an aerobic exercise protocol was more effective than the current standard of care for recovery from PCS.
• The literature search returned 17 possible studies related to the clinical question, of which 4 studies10–13 met the inclusion criteria and were included.
• The 4 studies10–13 included reported using aerobic exercise as a therapeutic intervention for PCS.

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Participants who completed controlled subsymptomatic aerobic exercise experienced a greater rate of symptom improvement from baseline assessment for follow-up.\textsuperscript{10–13} Subsymptomatic threshold can be determined through the Buffalo Concussion Treadmill test, Balke protocol, or Borg rating of perceived exertion (RPE). Patients with a concussion are not able to achieve maximum exertion. Symptom exacerbation occurs at a submaximum level.\textsuperscript{6,12–14} Athletes responded to subsymptomatic threshold training faster than nonathletes.\textsuperscript{13}

**Clinical Bottom Line**

There is moderate evidence to support subsymptomatic aerobic exercise as a treatment of PCS; therefore, it should be considered as a clinical option for reducing PCS and prolonged concussion symptoms. Clinicians should use a previously validated protocol to determine subsymptomatic threshold, including the Buffalo Concussion Treadmill test, Balke protocol, and Borg RPE.\textsuperscript{6,12–14} Although a specific timeline for duration of treatment has not been validated, there is evidence that 6 weeks of aerobic activity at 80% of subsymptom baseline may be effective in PCS treatment.\textsuperscript{10–13} Clinicians should utilize an individualized plan of care that includes patient baseline scores and personalized progression based on subsymptomatic threshold values.

**Strength of Recommendation**

Level C evidence exists that aerobic exercise protocol is more effective than the current standard of care in treating PCS.

**Search Strategy**

**Terms Used to Guide Search Strategy**

- Patient/Client group: participants with PCS or prolonged symptoms
- Intervention/Assessment: aerobic exercise
- Comparison: current standard care
- Outcome(s): symptom improvement or readiness to return to activity
- Time: concussion symptoms lasting longer than 4 weeks

**Sources of Evidence Searched**

- The Cochrane Library
- MEDLINE
- CINAHL
- SPORTDiscus
- Additional resources obtained via review of reference lists and hand search

**Inclusion and Exclusion Criteria**

**Inclusion Criteria**

- Studies that investigated patients diagnosed with concussion or sport-related concussion
- Studies that investigated patients with PCS or prolonged symptoms lasting longer than 4 weeks
- Studies that investigated aerobic exercise as a therapeutic intervention
- Limited to English language
- Limited to the past 10 years (2008–2017)

**Exclusion Criteria**

- Studies that investigated pharmacological interventions for treatment of PCS
- Studies that investigated subsymptomatic aerobic exercise as a tool for determining readiness to return to activity

**Results of Search**

Four relevant studies\textsuperscript{10–13} were located and categorized as shown in Table 1 (based on Levels of Evidence).\textsuperscript{15} Of the 4 studies identified, 3 studies are case series and 1 study is a randomized control trial.

**Best Evidence**

The studies in Table 2 were identified as the best evidence and selected for inclusion in this critically appraised topic. These studies were selected because they explored aerobic exercise as treatment for PCS.

**Implications for Practice, Education, and Future Research**

Several therapeutic interventions have been recommended for patients who have prolonged recovery after sustaining a concussion.\textsuperscript{8} This review proposed aerobic exercise as a comparison to the current standard of care and found that there is moderate evidence to support subsymptomatic aerobic exercise as a treatment of PCS. Because of current limitations in the literature, it is important that clinicians use sound clinical judgment when implementing this treatment. Three of the 4 studies included in this paper are case series that lack external validity due to their lack of a control group and limited generalizability to other populations. However, there is sound theoretical evidence that this treatment may help some patients with PCS. Despite the limitations of the available research, we believe that the consistent positive results warrant utilization of such a protocol for patients suffering from PCS.

**Table 1 Summary of Study Designs of Articles Retrieved**

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>Study design</th>
<th>Number located</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1b</td>
<td>Randomized control trial</td>
<td>1</td>
<td>Kurowski et al\textsuperscript{12}</td>
</tr>
<tr>
<td>4</td>
<td>Case series</td>
<td>3</td>
<td>Leddy et al\textsuperscript{13}, Gagnon et al\textsuperscript{11}, and Chrisman et al\textsuperscript{10}</td>
</tr>
</tbody>
</table>
Table 2 Characteristics of Included Studies

<table>
<thead>
<tr>
<th>Study design</th>
<th>Leddy et al\textsuperscript{13}</th>
<th>Chrisman et al\textsuperscript{10}</th>
<th>Kurowski et al\textsuperscript{12}</th>
<th>Gagnon et al\textsuperscript{11}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>13 participants recruited from Buffalo Concussion Clinic with PCS</td>
<td>83 participants from Seattle Children’s Hospital, youth diagnosed with a concussion and symptoms lasting longer than 4 wk</td>
<td>30 adolescents with mild TBI</td>
<td>10 participants with sport-related concussion</td>
</tr>
<tr>
<td>Mean age</td>
<td>27.9 (14.3) y</td>
<td>14.9 (2.3) y old</td>
<td>12–17 y</td>
<td>14–18 y</td>
</tr>
<tr>
<td>Inclusion criteria</td>
<td>(1) Prolonged symptoms at rest for greater than or equal to 6 wk; (2) Had symptom exacerbation during 2 graded treadmill exercise tests; and (3) Low cardiac risk</td>
<td>(1) Seen for concussion &gt;1 mo but &lt;300 d after their concussion; (2) Completed Balke treadmill test; and (3) Seen by a physical therapist in the SSTEP program at least twice</td>
<td>(1) Presence of at least 3 of 8 symptoms of PCS; (2) Exacerbation of symptoms with physical activity; and (3) Persistent symptoms lasting longer than 4 wk</td>
<td>No exclusion criteria were given</td>
</tr>
<tr>
<td>Exclusion criteria</td>
<td>(1) Lived too far from clinic; (2) Psychiatric diagnosis; (3) Injury occurred more than 1 y ago; (4) Cervical disk herniation; and (5) Inability to understand English</td>
<td>No exclusion criteria were given</td>
<td>(1) Severe TBI; (2) Taking medications or other physical therapy as treatment; (3) Preexisting cognitive disorders; and (4) Preexisting cardiovascular problems</td>
<td>Exclusion criteria: Coexisting cervical, oculomotor, and/or vestibular impairments</td>
</tr>
<tr>
<td>Intervention investigated</td>
<td>Participants performed a treadmill exercise test using the Balke protocol until symptom exacerbation</td>
<td>Participants performed a treadmill exercise test using the Balke protocol until symptom exacerbation</td>
<td>Participants performed an aerobic bike test, assessing Borg RPE and increasing intensity every 5 min</td>
<td>Participants completed a 4-part rehabilitation program for 6 wk: (1) Submaximal aerobic training for 15 min; (2) Coordination exercises; (3) Visualization and imagery; and (4) Daily home exercises</td>
</tr>
<tr>
<td>Symptoms: Heart rate and blood pressure were recorded to determine threshold</td>
<td></td>
<td>Intensity increased until the participant reached 30 min or RPE of 16</td>
<td>60% of maximum heart rate was determined by calculating maximum heart rate with the 220-age formula</td>
<td></td>
</tr>
<tr>
<td>Participants performed aerobic exercise for the same duration as the prior treadmill test at 80% of the maximum treadmill heart rate at a frequency of once per day for 5 or 6 d of the week</td>
<td></td>
<td>The intervention group performed the aerobic biking at 80% of the initial bike test for 5 or 6 times per week for 6 wk. The stretching groups completed a full-body stretching program with new stretches each week</td>
<td>Participants had a choice between walking/light jogging or stationary bicycle for the aerobic activity</td>
<td></td>
</tr>
<tr>
<td>Outcome measure(s)</td>
<td>(1) Symptoms (2) Maximum heart rate (3) Systolic blood pressure (4) Diastolic blood pressure (5) Achievement of maximal exertion</td>
<td>(1) Symptoms (type, severity, and duration) (2) Maximum heart rate (3) Systolic blood pressure (4) Diastolic blood pressure (5) Exercise duration</td>
<td>(1) Symptoms (type and severity) (2) RPE (3) Adherence to program</td>
<td>(1) Symptoms (2) Mood and energy level</td>
</tr>
</tbody>
</table>

(continued)
Table 2  (continued)

<table>
<thead>
<tr>
<th></th>
<th>Leddy et al\textsuperscript{13}</th>
<th>Chrisman et al\textsuperscript{10}</th>
<th>Kurowski et al\textsuperscript{12}</th>
<th>Gagnon et al\textsuperscript{11}</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main findings</strong></td>
<td>After 3 mo, 10 out of 12 participants reported to be symptom free at rest</td>
<td>Duration and severity of symptoms decreased as shown in SCAT 2 scores</td>
<td>The subsymptomatic exacerbation aerobic training group experienced greater rate of improvement than the full-body stretching group</td>
<td>Participants’ symptoms scores significantly decreased from baseline to 6-wk follow-up</td>
</tr>
<tr>
<td></td>
<td>Symptom total was a mean of 9.67 (5.87) at baseline and 5.42 (4.54) at follow-up; ( P = .002 )</td>
<td>Mean SCAT 2 scores: Baseline (&lt; 6 \text{ wk} = 36.3, SE = 3.68 ) Baseline 6-12 wk ( = -5.58, SE = 5.23 ) Baseline ( &gt; 12 \text{ wk} = 10.0, SE = 6.07 )</td>
<td>At baseline, the aerobic training group had a mean symptom score of 57.4 and the stretching group had a mean symptom score of 40.3</td>
<td>Symptom total was a mean of 17.4 (12.3) at baseline and 2.7 (3.2) at 6-wk follow-up; ( P = .004 )</td>
</tr>
<tr>
<td></td>
<td>Exercise time improved from baseline at 9.75 (6.73) min to 18.67 (2.53) min</td>
<td>None of the participants experienced worsening of symptoms</td>
<td>None of the participants experienced worsening of symptoms</td>
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</tr>
<tr>
<td></td>
<td>Athletes responded to subsymptomatic threshold exercise training faster than nonathletes</td>
<td></td>
<td>After final assessment, aerobic training group has a mean symptom score of 4.17 and stretching group 15.93; ( P = .04 )</td>
<td>Treatment duration lasted 6.8 (4.7) wk</td>
</tr>
<tr>
<td><strong>Level of evidence</strong></td>
<td>4</td>
<td>4</td>
<td>1b</td>
<td>4</td>
</tr>
<tr>
<td><strong>Validity score (if applicable)</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>PEDro score: 9/10</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Conclusion</strong></td>
<td>Controlled subsymptomatic threshold exercise was beneficial in decreasing symptoms of PCS</td>
<td>Aerobic exercise decreased PCS symptoms exponentially</td>
<td>Subsymptomatic aerobic exercise was more beneficial in decreasing PCS symptoms than full-body stretching</td>
<td>Aerobic exercise program greatly reduced PCS symptoms</td>
</tr>
<tr>
<td></td>
<td>Participants who completed controlled subsymptomatic threshold exercise had a decrease in symptoms of PCS from baseline to follow-up at 3 mo</td>
<td>Participants continued the Balke Treadmill Concussion test until total symptom resolution</td>
<td>Participants who completed the subsymptomatic exacerbation aerobic exercise protocol experienced a greater rate of symptom improvement than the full-body stretching group</td>
<td>In these participants who complete the aerobic exercise program, symptoms improved from baseline to follow-up at 6 wk</td>
</tr>
<tr>
<td></td>
<td>Further research should include assessment of cognitive performance</td>
<td>Further research needs to follow recovery time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: PCS, postconcussion syndrome; TBI, traumatic brain injury; RPE, rating of perceived exertion; SSTEP, subsympotm threshold exercise program; SCAT, Sport Concussion Assessment Tool; N/A, not applicable.
In patients who suffer from PCS and prolonged symptoms, 3 or more of the following symptoms are included: headache, dizziness, fatigue, irritability, insomnia, concentration problems, or memory difficulty; current recommendations suggest preliminary evidence is available to support the implementation of controlled subsymptomatic aerobic exercise.7,8 The subsymptomatic threshold should be determined using a validated measure like the Buffalo Concussion Treadmill test, Balke protocol, or Borg RPE. All 4 studies identified a treatment period of 6 to 9 weeks, with daily treatment at the subsymptomatic level that was predetermined through baseline testing. Three of the studies10,11,13 suggested daily aerobic exercise should last 15 to 20 minutes, and the other study12 required 30 minutes. By determining subsymptomatic threshold, patients can participate in subsymptomatic aerobic exercise to tolerance. This coincides with current concussion management recommendations, which focus on avoiding symptom exacerbation.7,16

Furthermore, there are emotional benefits of exercise as treatment of PCS. Exercise gives patients increased self-efficacy; less anxiety, stress, and depression; and better overall well-being.17,18 Regular exercise has shown to have cognitive benefits in improving cognitive function, sleep, learning, and memory.17,18 Athletes, who are conditioned to an active lifestyle, may be at risk of feeling isolated and removed during concussion recovery. An active approach to their rehabilitation might help improve overall cognitive function, decrease depression and isolation, and restore an active lifestyle that will help to promote healing.20 Leddy et al13 found that athletes responded to the aerobic exercise program faster than nonathletes, suggesting that aerobic exercise was beneficial specifically for athletes.

Although the current evidence for using submaximal exercise is promising, the level of evidence is low due to study design, number of participants, and population. However, a recent systematic review identified that it may be beneficial.8 Further research should include randomized controlled trials with large sample sizes and uniform control measures. Only 1 study identified the participants as having sport-related concussion,11 whereas 2 other studies identified and compared the participants’ mechanism of injury as sport-related concussion or another mechanism.10,11 More research should be completed with a focus on individual populations, such as sport-related concussion, as there may be benefit of aerobic activity in those active prior to the injury.20

This critically appraised topic should be reviewed in 2 years, or when additional best evidence becomes available, to determine whether additional best evidence has been published that may change the clinical bottom line for the research question posed in this review.

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References
17. Hogan CL, Catalino LI, Mata J, Fredrickson BL. Beyond emotional benefits: physical activity and sedentary behaviour affect psychosocial

Subsymptomatic Exercise Protocol 215

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