

Practical Management: Prescribing Subsymptom Threshold Aerobic Exercise for Sport-Related Concussion in the Outpatient Setting

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Abstract: Exercise intolerance is an objective biomarker of the physiological dysfunction after sport-related concussion (SRC). Several trials have established the safety and clinical efficacy of subsymptom threshold aerobic exercise prescribed within 1 week of injury as treatment for SRC. Clinicians, however, may not be comfortable prescribing aerobic exercise after SRC. This article presents 3 methods of exercise prescription for patients with SRC. The first requires a graded exertion test plus a home-based exercise program requiring a heart rate (HR) monitor. The second requires a graded exertion test but no HR monitor for home-based exercise. The third requires solely an HR monitor to safely progress through the home-based exercise prescription. Patients are encouraged to keep a symptom and exercise diary and return for re-evaluation every 1 to 2 weeks. Delayed recovery should prompt the clinician to evaluate for other potential symptom generators (eg, cervical, vestibular, oculomotor, mood, or migraine disorders).

Key Words: concussion, sport-related concussion, exercise treatment, subsymptom threshold aerobic exercise, Buffalo Concussion Treadmill Test

(*Clin J Sport Med* 2020;00:1–4)

INTRODUCTION

The yearly incidence of sport-related concussion (SRC) in the United States is immense and is considered to be a matter of public concern.¹ Spontaneous recovery from SRC usually occurs within 2 to 3 weeks; however, up to 15% to 30% of patients take longer.² Symptoms present for more than 2 weeks in adults or 1 month in adolescents is called Persistent Postconcussive Symptoms (PPCS).² The management of SRC and PPCS has changed significantly over the years. The first Concussion In Sport Group (CISG) statement in 2001 recommended strict rest until asymptomatic, followed by a gradual return-to-sport.³ This statement was based on expert opinion that relied on animal research that reported early and forced exercise initiation after simulated concussion interfered with cognitive recovery.⁴ More recent research, however, has not shown that prolonged rest is effective after

SRC.⁵ Conversely, emerging research suggests that moderate levels of spontaneous, as well as prescribed physical activity, may help patients recover after SRC.⁵ The most recent CISG statement in 2016 now recommends a brief period of relative rest (24-48 hours) followed by a gradual return to activity.²

In a recent randomized controlled trial, Leddy et al⁶ compared 20 minutes of daily progressive subsymptom threshold aerobic exercise [defined as 80% of the heart rate threshold (HR_t) achieved on a weekly Buffalo Concussion Treadmill Test (BCTT)] with a placebo-like progressive stretching program. The aerobic exercise arm recovered significantly faster than the stretching arm and had a non-significant trend toward a lower incidence of PPCS. Nevertheless, physicians may not be comfortable prescribing individualized subsymptom threshold exercise as it requires skilled personnel to perform treadmill testing, knowledge about how to prescribe and advance the appropriate exercise intensity, and HR monitors, so that patients exercise within specific intensity parameters to avoid overexertion. The purpose of this article is to provide clinicians with a more clinically feasible method to prescribe subsymptom threshold exercise for concussion treatment.

EXERCISE TOLERANCE ASSESSMENT

Exercise intolerance, which is defined as the inability to exercise near to age-appropriate maximum HR due to exacerbation of concussion-related symptoms, is considered to be a clinical manifestation of autonomic physiological dysfunction after SRC and in some cases of PPCS.^{7,8} Exercise intolerance after concussion is hypothesized to be due to impairment of the Autonomic Nervous System's (ANS) regulation of cerebral blood flow that may be due to damage to the central ANS centers and/or uncoupling of the central ANS from the cardiovascular system.⁹ Progressive submaximal exertional tests, such as the BCTT¹⁰ and the Buffalo

Submitted for publication May 27, 2019; accepted October 26, 2019.

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Research reported in this publication was supported by the National Institute of Neurological Disorders and Stroke of the National Institutes of Health under award number 1R01NS094444 and by the National Center for Advancing Translational Sciences of the National Institutes of Health under award number UL1TR001412 to the University at Buffalo. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

The authors report no conflicts of interest.

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Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.cjsportmed.com).

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http://dx.doi.org/10.1097/JSM.0000000000000809

Concussion Bike Test (BCBT),¹¹ reliably determine the degree of exercise intolerance after SRC. The BCTT and BCBT gradually increase workload to determine the level of stress the ANS can tolerate before deviating from homeostatic equilibrium and producing symptoms.⁸

Buffalo Concussion Treadmill Test

The BCTT¹⁰ protocol begins with the patient's report of concussion symptom severity at rest on a Visual Analog Scale (VAS, range 0-10). The patient then walks on a level treadmill at 3.2 mph at 0 degree incline (3.6 mph if participant is 5'10" and above). The treadmill gradient is increased by 1 degree each minute until 15%, after which the speed is increased by 0.4 mph each minutes. Heart rate, VAS, and rating of perceived exertion (RPE, Borg scale, range 6-20) are recorded at the end of each stage until symptom exacerbation or voluntary exhaustion, followed by a 2-minute cool-down period at 2 mph and level grade. Symptom exacerbation is defined as an increase of 3 points or more from the pre-exercise VAS value (a point or more for increase in severity and a point for appearance of a new symptom). Voluntary exhaustion is defined as a value of ≥ 17 on the RPE scale. An examiner also observes for visible signs of distress, which may prompt test cessation. Termination of the test for symptom exacerbation before maximum exertion defines exercise intolerance, and the HR at which symptom exacerbation occurs (3-point increase on the VAS) is the HRt. Termination of the test due to voluntary exhaustion or achievement of approximately 85% to 90% of age appropriate maximum HR is indicative of normal exercise tolerance. It is important to note that early exercise intolerance (symptom exacerbation at $< 70\%$ of age-predicted maximum) is characteristic of physiological dysfunction from concussion.¹⁰ Exercise cessation beyond 70% of age-predicted maximum may be seen in patients with cervical strain or isolated vestibulo-ocular dysfunction. Patients with cervical and/or vestibulo-ocular sources of symptoms should be referred for appropriate therapy since aerobic exercise alone may not resolve these issues. The BCTT manual is provided as an online supplementary file (see **Supplemental Digital Content 1**, <http://links.lww.com/JSM/A229>).

Buffalo Concussion Bike Test

The BCBT¹¹ is a cycle ergometer test designed for patients with significant vestibular dysfunction or orthopedic injuries that prevent safe use of a treadmill. The procedure for the BCBT is similar to the BCTT except that (1) patients exercise on a cycle ergometer (upright or recumbent) at 60 (± 5) rpm at a specific resistance based on body weight (kg) and (2) each stage is 2 minutes. Heart rate, VAS, and RPE are recorded every 2 minutes until symptom exacerbation or voluntary exhaustion, followed by a 2-minute cool-down at 30 rpm. The BCBT manual is provided as an online supplementary file (see **Supplemental Digital Content 2**, <http://links.lww.com/JSM/A230>).

EXERCISE TREATMENT

Although subsymptomatic exercise appears to be beneficial for SRC and PPCS, exercise that is too intense may increase symptoms and prolong recovery.^{12,13} Patients are instructed

that if symptom severity during exercise outside of the clinic increases by more than 2 points from their pre-exercise value on the 1 to 10 scale, they should stop exercising and continue the next day at a lower exercise intensity. Those who do not experience symptom exacerbation may extend the duration of exercise (ie, from 20 to 30 minutes or more) keeping the HR/intensity steady. Submaximal steady-state aerobic exercise is recommended over power resistance or intense exercise such as rowing that create fluctuating and unpredictable HRs. Swimming is an ideal form of aerobic exercise, but subjects may find it difficult to actively monitor HR. Outdoor cycling is not recommended initially as vestibular dysfunction may increase the risk of further trauma. The authors recommend brisk walking, jogging, and stationary biking for each of the exercise prescription methods described below. Delayed recovery from SRC despite return of good exercise tolerance should prompt the clinician to evaluate other potential symptom generators. In cases where the lowest exercise prescription (stage 1) elicits significant symptom exacerbation, physical rest is indicated.² Patients are encouraged to keep a daily diary of exercise performance and symptoms. We present 3 methods of prescribing exercise based on availability of exercise testing and home HR monitors (Figure).

Method 1: Exercise Prescription With Exertion Testing and Heart Rate Monitor

The exercise prescription is calculated as $90\% \pm 5$ bpm of the HRt achieved on exercise testing. The patient is advised to perform a 5-minute warm-up to the target HR followed by at least 20 minutes of aerobic exercise at the target HR. Patients are instructed to monitor their symptom level during exercise using the VAS from the exercise test. If symptoms do not increase by 2 or more points from the baseline value, patients may continue until symptom exacerbation or fatigue. After symptom exacerbation, the patient is instructed to cool down for at least 2 minutes. Ideally, the patient should return for exercise testing every 1 to 2 weeks to establish a new target HR or to determine resolution of exercise intolerance. If the patient experiences a drastic increase in symptoms during exercise at home, the patient should stop, rest, and exercise at a lower HR the following day. If symptom exacerbation persists or becomes worse the following day, patients are advised to contact their physician. A sample home-based exercise prescription handout is provided as a supplementary file (see **Supplemental Digital Content 3**, <http://links.lww.com/JSM/A231>).

Method 2: Exercise Prescription With Exertion Testing but Without a Heart Rate Monitor

Patients may not have access to an HR monitor, and nonathletic patients and younger adolescents may find it easier to follow a workload-based (speed) prescription in lieu of an HR monitor. The non-HR monitor-based exercise prescription method requires identification of the stage at which symptom exacerbation occurs on the BCTT or BCBT. The handout is designed, so that the physician may highlight (on the handout) the stage which the patient should begin their prescription according to their BCTT/BCBT results, giving the patient several exercise options in terms of gradient and setting. The exercise prescription uses different treadmill speeds for different heights: one for patients under

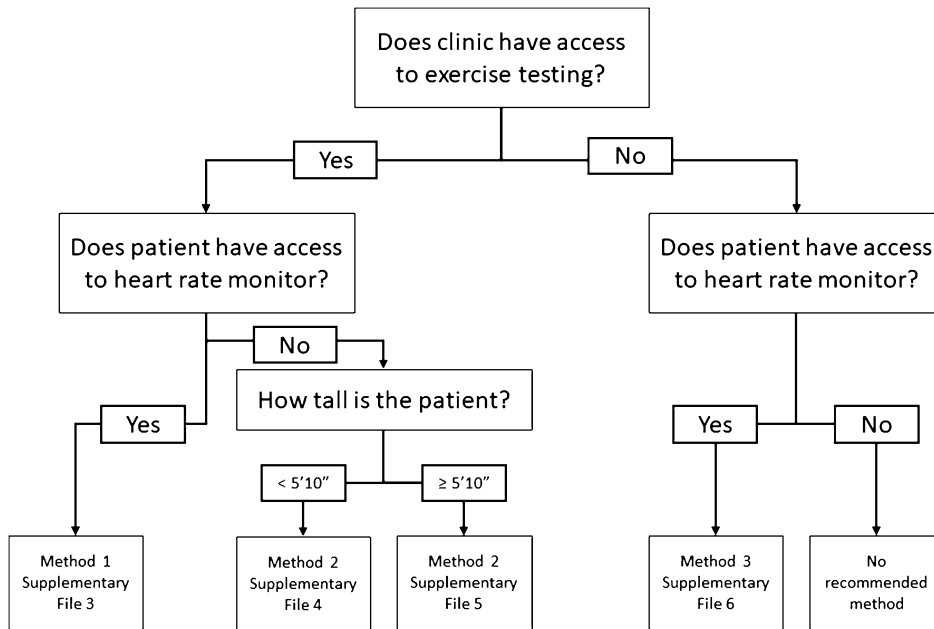


Figure. Summary of exercise prescription methods.

5'10" and one for patients 5'10" and above. The prescription is based on 90% of the Metabolic Equivalent of Task (METs) calculated from the workload (using speed and gradient variables) of each stage through the ACSM walking equation.¹⁴ The ACSM jogging equation is then used to extrapolate jogging paces in both mph and minutes per mile (mpm) at varying gradients, allowing patients to exercise at a pace of their choosing without compromising intensity. The ACSM jogging equation yields a more conservative prescription than the ACSM walking equation for patients who experience exercise intolerance at earlier stages, which indicates more severe physiological dysfunction, and establishes a more precise prescription for those who are less exercise intolerant or further along in recovery. Extrapolation to several gradients and settings, including the conversion from mph to mpm, makes the prescription adaptable to individual patient preference. Since most modern aerobic exercise equipment has a METs setting, we include a raw 90% METs prescription to allow patients to exercise on the modality of their choosing, such as cycle ergometers or elliptical machines. Patients can progress their exercise prescription at home using the criteria described on the sample exercise prescription handouts (see **Supplemental Digital Contents 4 and 5**, <http://links.lww.com/JSM/A232> and <http://links.lww.com/JSM/A233>, respectively).

Method 3: Exercise Prescription Without Exertion Testing

Graded exercise testing allows for determination of exercise tolerance and optimal individualization of the exercise prescription. In its absence, a prescription must begin conservatively so not to exceed the level of physiological stress the ANS can tolerate and exacerbate symptoms beyond rehabilitative value. An HR monitor is required for this prescription method. Age appropriate maximal HR (HR_{max}) is calculated using the Karvonen equation¹⁵

(HR_{max} = 220 – age), which is used to create intervals starting at 50% of HR_{max} and increasing to 80% of HR_{max} by 5% intervals. These intervals serve as recovery “stages.” Stage 1 is an intensity of 50% of age appropriate maximal HR for 20 minutes, taking note of the symptom score before and during exercise. The difference in the symptom scores determines the stage for the following day. A symptom increase of 0 or 1 point means that the patient moves on to the next stage of recovery, increasing the target HR by 5% HR_{max}. A symptom increase of 2 on the VAS represents the desired exercise intensity for rehabilitation. This HR is maintained until no symptom increase is observed for 2 contiguous days, after which the patient advances to the next stage and continues to progress through recovery. A symptom increase of 3 points or more means the prescription is too intense and the patient should return to the previous stage. The patient must then experience no symptom increase for 2 days to move to the next stage (see **Supplemental Digital Content 6**, <http://links.lww.com/JSM/A234>).

LIMITATIONS

These methods of exercise prescription require patient effort and may not be preferred by patients who are not used to, or do not want to, perform physical exercise. Some patients may not understand the hazards of performing intense exercise or exercise with a high risk of head injury, for example, outdoor cycling despite vestibular dysfunction. These methods have not been used in preadolescent kids (<12 years), and very short patients may require more specific adjustment to the home exercise prescription.

CONCLUSIONS

Subsymptom threshold aerobic exercise is emerging as a treatment for concussion. Nevertheless, physicians may

not have the equipment for or be comfortable with prescribing individualized subsymptom threshold exercise. This article provides clinicians with 3 choices for prescribing subsymptom threshold exercise that involve (1) a graded exertion test with an HR monitor; (2) a graded exertion test without an HR monitor; and (3) an HR monitor without the need for a graded exertion test. Patients are encouraged to keep a symptom and exercise diary and return for re-evaluation every 1 to 2 weeks. Delayed recovery from SRC despite return of normal exercise tolerance indicates that other symptom generators should be investigated.

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