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Active Recovery from Concussion

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Abstract

Purpose of review: Recent studies are challenging the utility of prolonged rest as treatment for concussion and post-concussion syndrome (PCS). The purpose of this paper is to review the evidence for active recovery from concussion and PCS.

Recent findings: Emerging data identify the central role of autonomic nervous system (ANS) dysfunction in concussion pathophysiology. The exercise intolerance demonstrated by athletes after sport-related concussion (SRC) may be related to abnormal ANS regulation of cerebral blood flow (CBF). Since aerobic exercise training improves ANS function, sub-threshold exercise treatment is potentially therapeutic for concussion. A systematic assessment of exercise tolerance using the Buffalo Concussion Treadmill Test (BCTT) has been safely employed to prescribe a progressive, individualized sub-threshold aerobic exercise treatment program that can return patients to sport and work. Multiple studies are demonstrating the efficacy of an active approach to concussion management.

Summary: Sustained rest from all activities after concussion, so called “cocoon therapy”, is not beneficial to recovery. Evidence supports the safety, tolerability, and efficacy of controlled sub-threshold aerobic exercise treatment for PCS patients. Further study should determine the efficacy and optimal timing, dose, and duration of sub-threshold aerobic exercise treatment acutely after concussion because early intervention has potential to prevent PCS.

Keywords

concussion; exercise; treatment; autonomic nervous system; treadmill

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Conflicts of interest

The authors have none to declare.

Introduction

Research based upon animal studies (1, 2) and recent human data (3) demonstrate that the concussed brain is in a vulnerable state that places it at increased risk of delayed recovery should it sustain more trauma or experience undue physiological stress (such as continuing to play in a game with concussion symptoms) before metabolic homeostasis has been restored. A consequence of this is that clinicians have traditionally advised strict physical and cognitive rest after concussion until all symptoms resolve. (4, 5) There is, however, no empirical evidence that prolonged ‘radical rest’ is therapeutic (4, 6) and most persons do not live their normal lives in an asymptomatic state.(7) The concept of “rest until asymptomatic” has also been recommended for patients with prolonged symptoms after concussion, which is called post-concussion syndrome (PCS).(4, 6) Post-concussion syndrome is defined as symptoms for more than 2 weeks in adults and more than 4 weeks in adolescents and children. (8) Recent clinical and experimental studies are, however, beginning to challenge the utility of prolonged rest as treatment for concussion and PCS.(4, 9, 10) The most recent statement from the International Concussion in Sport Group (CISG, Berlin 2017) recommends an initial period of rest during the first 24–48 hours followed by gradual return to school and social activities (prior to contact sports) in a manner that does not result in a significant exacerbation of symptoms and that “further research evaluating rest and active treatments should be performed ...”. (8) The purpose of this paper is to review the emerging evidence for active recovery from concussion and PCS and potential physiological mechanisms for its efficacy.

Role of the autonomic nervous system in concussion

A recent systematic review from the CISG found that multiple studies suggest physiological dysfunction outlasts current clinical measures of recovery from sport-related concussion (SRC), supporting a buffer zone of gradually increasing activity before return to full contact sport and associated risk.(11) The autonomic nervous system (ANS), directed primarily from the brainstem, maintains function of the cardiac and pulmonary systems as well as a host of other physiological processes.(12) It is not known whether autonomic dysfunction after concussion reflects injury to specific brain areas involved in autonomic control or is a reflection of diffuse brain injury. Studies have revealed neurophysiological disturbances in the cortex after concussion (11) as well as white matter changes in the brainstem on MRI Diffusion Tensor Imaging (DTI). (13) The putative mediators for autonomic dysfunction are not fully established but there is some preliminary evidence for altered central chemosensitivity after concussion. The cells that sense the arterial carbon dioxide tension (PaCO_2) in the blood are located in the brainstem near the autonomic control centers for cardiopulmonary function. In a recent controlled study,(14) collegiate female athletes with PCS had abnormally low sensitivity to the PaCO_2 (i.e., they did not breathe as much as they should have for a given level of arterial CO_2) that caused a relative hypoventilation during exercise that in turn raised their PaCO_2 levels out of proportion to exercise intensity. Cerebral blood flow (CBF) is directly proportional to PaCO_2 ; hence, elevated PaCO_2 raised exercise CBF disproportionately to exercise intensity, which was associated with symptoms of headache and dizziness that limited their exercise tolerance to low levels. Since aerobic exercise training is a well-recognized non-pharmacological approach for enhancing

sympatho-vagal ANS balance,(15) aerobic exercise as a treatment conceivably could improve autonomic function in concussed patients. Subjects in this study performed the Buffalo Concussion Treadmill Test (BCTT), a systematic evaluation of the exercise capacity of concussed patients that has been shown to be safe (16) and reliable (17) for assessing post-concussive symptoms. Based on the heart rate (HR) attained at the level of symptom exacerbation on the treadmill, subjects performed a daily individualized sub-threshold HR progressive aerobic exercise program to the level of their symptom exacerbation. Sub-threshold exercise normalized their CO₂ sensitivity, exercise ventilation, PaCO₂, CBF, and exercise tolerance, in association with resolution of symptoms. Thus, sub-threshold aerobic exercise had a beneficial effect on the central physiology of the concussed brain in active patients suffering with PCS. In a different study, Leddy et al. showed that aerobic exercise treatment restored abnormal local CBF regulation (as indicated by brain functional MRI activation patterns) to normal in PCS patients whereas a placebo stretching program did not. (18) These studies suggest that some concussion symptoms and exercise intolerance may be related to abnormal ANS regulation of CBF and that individualized, sub-threshold aerobic exercise treatment may restore CBF regulation and exercise tolerance to normal and improve outcome.

Recent emerging data are confirming the central role of ANS dysfunction and altered control of CBF in concussion pathophysiology, both early after injury and in those with prolonged symptoms. Heart rate variability (HRV) is a measure of the normal variation in heart rate that indicates the balance between the parasympathetic and the sympathetic branches of the ANS. In the frequency domain, high frequency (HF) HRV is a marker for parasympathetic activity whereas low frequency HRV is a marker for both parasympathetic and sympathetic activity. Low HRV (i.e., an indicator of sympathetic nervous system predominance) is associated with clinical severity and mortality in conditions such as cardiovascular disease (19) and depression.(20) Johnson et al. studied the response to face cooling in collegiate athletes within one week of SRC. (21) Cooling the forehead, eyes, and cheeks (i.e., face cooling) stimulates the trigeminal nerve to evoke transient increases in cardiac parasympathetic activity (~1–2 minutes) followed by sustained increases in sympathetic activity.(22) Eleven symptomatic collegiate athletes (5 females) within 10 days of concussion were compared with ten age- and sex-matched healthy controls. The concussed athletes had significantly blunted cardiac parasympathetic (HF HRV) and sympathetic (HR and blood pressure) activation during face cooling when compared with controls, indicating an inability to switch to the proper branch of the ANS when subjected to a stressful physiological condition. Similarly, Bishop et al. (23) found dysregulated autonomic function within the initial 72 hours of concussion on measures of cardiovascular metrics under resting and baroreflex conditions using a squat to stand maneuver. Dobson et al. (24) found that concussed athletes had significantly greater resting systolic blood pressure (SBP), greater SBP responses to standing, and prolonged 90% SBP normalization times after the Valsalva maneuver within 48 hours of SRC. The differences subsided 24 hours later. Hutchison et al. (25) examined psychological (mood, stress, sleep quality, and symptoms) and physiological (HRV and salivary cortisol) measures in concussed athletes over clinical recovery milestones. Psychological measures were significantly worse for concussed athletes relative to controls in the acute symptomatic phase but significantly better at return-to-play (RTP).

The cardiac response of female athletes was more sensitive to concussion compared with males, and females and concussed athletes demonstrated reduced HF HRV extending into the post-RTP phase. Conversely, male athletes showed greater suppression of LF HRV associated with mood disturbances. The authors concluded that concussed athletes had resolution of mood disturbances, symptoms, and sleep quality by RTP while ANS dysfunction (reduced HRV) was measured beyond RTP, which is consistent with recent observations of persistent physiological disturbances despite clinical recovery in some patients after SRC. (11)

Exercise testing as a safe diagnostic and prognostic tool

The diagnosis of concussion can be challenging because most clinicians are not present at the time of injury and the symptoms after concussion are non-specific. For example, symptoms after head injury, including cognitive symptoms, do not always discriminate between concussion and cervical/vestibular injury. (26) As discussed above, there is evidence of altered control of CBF during exercise, which may be one reason for the reduced exercise tolerance observed in some athletes after SRC.(14) Exercise intolerance is defined as stopping exercise because of symptom-exacerbation prior to attaining maximum exercise performance. (14) Research suggests that exercise intolerance is a physiological sign of concussion.(27) In a recent prospective randomized controlled trial (RCT) of adolescent athletes within one week of SRC who were randomly assigned to perform the BCTT or not, exercise intolerance was present in all subjects independent of physician diagnosis.(28) Of further clinical value, this RCT found that the degree of early exercise intolerance on the test, i.e., the lower the HR threshold at the time of symptom exacerbation, was the strongest predictor of delayed recovery (symptoms beyond 4 weeks) in adolescents after SRC. Furthermore, return of normal exercise tolerance coincided with clinical diagnosis of concussion recovery. The safety of the BCTT, provided the a-priori stopping criteria are adhered to, has been confirmed both in adults (28) and in pediatric patients.(29)

A recent systematic review found that the strongest evidence indicates that exertional assessments can provide important insight about mild traumatic brain injury (TBI) recovery and should be administered using symptoms as a guide.(30) Others are even beginning to use graded aerobic treadmill testing to safely assess exercise tolerance in patients with more moderate to severe head trauma.(31) Thus the emerging evidence suggests that symptom-limited assessment of exercise tolerance can safely be used by clinicians to evaluate patients with PCS, as well as in adolescents within the first week after SRC, and potentially provide a physiological indicator of concussion severity beyond the level of initial symptom burden. Furthermore, return of exercise tolerance to the level that is normal for the patient appears to be an indicator of cardiovascular and cerebrovascular physiological recovery from concussion, which would help clinicians more objectively make the difficult return-to-sport/activity decision for active patients. (32)

Concussion management: Rest vs. Active Therapy

Recent reviews are providing evidence that prolonged physical and cognitive rest may not be as effective for concussion and PCS management as once thought. The 2017 CISG

systematic review of rest and treatment/rehabilitation following SRC (33) concluded that patients should be encouraged to gradually increase activity after a brief period (24–48 hours) of cognitive and physical rest and that interventions including cervical and vestibular rehabilitation, cognitive behavioral therapy, multifaceted collaborative care, and closely monitored sub-symptom threshold exercise may be of benefit. In a systematic review and meta-analysis of exercise after concussion, Lal et al. (34) found support for physical exercise improving the symptom scores in patients after concussion. Mahooti (35) concluded that prolonged physical and cognitive rest may impede recovery and lead to mood and/or anxiety disorders in concussed patients. One review found level C evidence that any sub-symptomatic aerobic exercise program is more effective for treating PCS than current standard of care.(36)

There are no clear guidelines for how much rest is beneficial and the timing of when it may be appropriate to initiate physical activity or to prescribe exercise after a concussion.(8) With respect to the acute recovery phase, Thomas et al. (9) randomly assigned patients aged 11 to 22 years old in a pediatric emergency department (ED) within 24 hours of concussion to strict rest for 5 days versus 1–2 days of rest followed by a stepwise return to activity. The 5 days strict rest group reported more daily post-concussive symptoms and slower symptom resolution. In a large prospective observational study of 3063 children and adolescents (5 to 18 years old) seen in the ED, subjects who reported early return to moderate levels of physical activity (e.g., jogging, non-contact sport practice) within 7 days of concussion when compared with those who did not engage in any physical activity during the first week had a significantly reduced risk of PCS at 28 days after injury (24.6% vs. 43.5%).(37) Thus, evidence is emerging that sustained rest after acute concussion may not result in faster symptom resolution and that early moderate levels of physical activity may help prevent some patients from experiencing a prolonged recovery.

In a large case series (n=277), Dobney et al. (38) showed that an individualized program of aerobic exercise, balance, and sport specific skills improved symptoms in children and adolescents (age 7 to 18 years) between three and four weeks post-injury. Lennon et al (39) categorized 120 patient records (mean age of 14.8 years) into 3 cohorts on the basis of the timing of physical therapy implementation following injury: 0–20 days (early intervention), 21 to 41 days (middle intervention), and 42 or more days following injury (late intervention). They found that timing of treatment intervention did not significantly affect outcome. In a retrospective cohort study of 83 youth with symptoms more than one month (76% SRC) who participated in individualized progressive sub-symptom threshold aerobic exercise based upon BCTT performance, Chrisman et al. (40) showed that symptoms decreased exponentially following initiation of progressive aerobic exercise regardless of symptom duration at presentation (<6 weeks, 6–12 weeks, >12 weeks) and no subjects reported worsening of symptoms. In a retrospective cohort study of 25 patients (12–20 years old) with PCS following SRC, Grabowski et al. (41) found that supervised PT consisting of sub-symptom cardiovascular exercise, vestibular/oculomotor therapy, and cervical spine rehabilitation improved symptom scores, exercise tolerance on graded exercise testing, and balance. In a single-site, parallel, open-label RCT, Chan et al. (42) compared treatment as usual (TAU) to TAU plus active rehabilitation in adolescents with PCS lasting >1 month after SRC. TAU consisted of symptom management and RTP advice, return-to-school

facilitation, and physiatry consultation. The active rehabilitation program involved a 6 week in-clinic sub-symptom threshold aerobic training program, coordination exercises, and visualization and imagery techniques with a physiotherapist plus a home exercise program. In-clinic symptom exacerbations occurred in 30% of aerobic training sessions but resolved within 24 hours in all instances. Active rehabilitation was associated with a greater reduction in symptoms than TAU. In the most informative prospective RCT to date, Kurowski et al. (43) compared sub-symptom aerobic training with full-body stretching in 30 adolescents with 4–16 weeks of persistent symptoms after mild TBI. After the first week of intervention, there was significantly greater rate of improvement in the sub-symptom threshold aerobic training group when compared with the full-body stretching group. These results suggest a physiological effect of aerobic exercise treatment beyond the placebo effect of a stretching program, which itself should not have affected cardiovascular function. The results of these studies are supporting the safety, tolerability, and potential efficacy of active rehabilitation for adolescents with PCS. A recent quasi-experimental study (*Leddy et al. in press*) showed that early (first week) prescribed sub-symptom threshold aerobic exercise after SRC safely sped recovery in male adolescents when compared with prescribed rest. Exercise treatment improved the panoply (physical, cognitive, sleep, and affective) of post-concussion symptoms in adolescents. Larger prospective replication studies are needed to verify the findings and improve generalizability.

Future Directions

It is becoming clear that sustained rest from all activities, sometimes called “cocoon therapy”, is not beneficial and may potentially be harmful to recovery from concussion, especially in athletes and active persons. Future work should focus on determining the optimal type, timing, and intensity of active rehabilitation programs and the characteristics of individuals most likely to benefit. Some authors are proposing to phenotype patients into categories that are amenable to specific therapies to improve outcome in those with prolonged recovery.(6, 44) Future studies should evaluate this approach to determine whether institution of sub-threshold exercise or other active rehabilitation techniques early after concussion can speed recovery. Perhaps most importantly, early active interventions after concussion have the potential to prevent some patients from going on to a prolonged recovery with its negative consequences for athletic, academic and vocational performance.

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Key points

1. Emerging data identify the central role of autonomic nervous system (ANS) dysfunction in concussion pathophysiology.
2. There is no evidence that sustained rest from all activities after concussion, so called “cocoon therapy”, is beneficial to recovery.
3. Emerging evidence supports the safety, tolerability, and efficacy of controlled sub-threshold aerobic exercise treatment for PCS patients.
4. Early active interventions after concussion should be studied for their potential to speed recovery and to prevent some patients from going on to PCS.