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CONCUSSION (C SENTER AND M KAPADIA, SECTION EDITORS)

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Treatment of Acute Sports-Related Concussion

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Abstract

Purpose of Review Here, we summarize the current scientific literature on the management of sports-related concussion (SRC) in the acute period (< 6 weeks post-injury) with a focus on rest, return to learn, return to play, and emerging treatments.

Recent Findings While relative rest is recommended for the first 24–48 h following acute SRC, the most recent guidelines highlight the lack of evidence for complete rest and in fact show that prolonged cognitive and physical rest can be detrimental. Gradual return to learn and play is recommended. Return to sport should only occur once the patient is symptom free. While there are no FDA-approved medications for acute treatment of concussion, there is preclinical data for the benefit of omega 3 fatty acids. Evidence is limited around the benefits of treating sleep disorders, vestibular-ocular dysfunction, and neck pain in the acute period.

Summary After 24–48 h of rest, SRC patients may gradually resume cognitive and physical activity. More research is needed to determine if any supplements, medications, and/or physical therapy are indicated in the management in acute SRC.

Keywords Sports-related concussion (SRC) · Return to learn · Return to play · Concussion treatment

Introduction

Sports-related concussion (SRC) is one of the most common types of mild traumatic brain injury (mTBI). There is an annual incidence of up to 2.8 million traumatic brain injuries in the USA, the vast majority accounted for by mild traumatic brain injuries (mTBI) [1]. With more than 44 million youth participating in organized sports, this accounts for a large percentage of the burden of injury [2].

Concussion management has evolved significantly over the past decade, swinging from complete cognitive and physical rest to more limited rest and earlier cognitive and physical activity. While the majority of concussed athletes improve rapidly during the first 2 weeks after injury, symptoms can persist in up to 10–30% of cases [3••, 4]. What follows is a review of the literature as it applies to the treatment of an athlete with an acute SRC. Unless otherwise noted, evidence included here pertains to treatment rendered within 6 weeks of SRC.

When in Doubt, Sit Out

Concussion causes a cascade of pathophysiological changes in the brain with numerous downstream effects. First, repair mechanisms are activated resulting in increased utilization of glucose for ATP generation [5, 6]. Second, cerebral blood flow is decreased resulting in a metabolic mismatch or "energy crisis," whereby demand outstrips supply [5]. While there is debate about "second impact syndrome," the concept that a second brain injury closely following a first may lead to catastrophic cerebral edema, there is evidence to suggest a period

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of vulnerability following an initial concussion during which occurrence of a second impact may prolong recovery [7]. Concerns about both the brain's energy crisis and this clinical period of neurologic vulnerability formed the basis for recommendations for acute rest after a concussion. Thus, when an athlete shows any signs or symptoms of a concussion, he or she should be removed from play. The athlete should be evaluated on the sideline by a physician or other licensed health care provider. If a concussion is suspected, the athlete should not return to play that day. The athlete should not be left alone, but should be monitored over the next several hours for any clinical deterioration that would increase concern for a more severe brain injury [3••]. This period of acute rest and avoidance of additional contact, collision, and energy expenditure seems beneficial. In a study of NCAA athletes, those who immediately came out of play at the time they recognized that they had concussion symptoms recovered more quickly than those athletes who continued to play through their symptoms and sought treatment later [8••].

How Much Rest Is Best?

A cornerstone of the acute treatment of SRC over the past 10 years or so has been rest. Multiple papers have recommended physical and cognitive rest until concussion symptoms resolve [9–12]. This was in part based on studies demonstrating that early return to school resulted in prolonged recovery. Specifically, a prospective study published in *Pediatrics* in 2014 that tracked average cognitive load at consecutive visits showed that increased cognitive activity was associated with longer recovery [10]. Other studies showed that excessive post-concussion physical activity worsened neurocognitive function [11]. Return to physical activity within 7–10 days was associated with high risk of repeat concussion in a cohort of NCAA football players, further supporting the concept of avoiding activity acutely post-concussion [12].

Due to the emphasis on rest after a concussion, many clinicians began to recommend rest from all physical and cognitive activities until symptom-free post-concussion. This led to the phenomenon of "cocooning," severely restricting all sensory, motor, and cognitive stimulation after SRC. As one can imagine, this led to prolonged school and work absence, resulting in social isolation, increased screen time usage, and detrimental effects on mood. Concussion management became increasingly complicated by more prevalent symptoms of anxiety, depression, and sleep disturbances [13].

"Rest is best" has recently been challenged by a growing body of literature suggesting that prolonged rest may actually slow the speed of recovery from a concussion. Animal studies show that voluntary exercise increases brain-derived neurotrophic factor and, thus, promotes neuron growth/repair [14, 15]. Some early human data suggest the same [16, 17]. A 2015 study in *Pediatrics* randomized patients aged 11–22 years who presented to a pediatric emergency department within 24 h of concussion to either strict rest for 5 days or usual care (defined as 1–2 days' rest, followed by a stepwise return to activity). Those in the 5-day rest intervention group had more daily post-concussive symptoms and slower symptom resolution [18]. Several studies have showed an association between early physical activity and decreased duration of post-concussive symptoms [19, 20].

Treating clinicians must carefully weigh the benefits of early cognitive and physical rest with the potential for prolonged recovery if rest is prescribed for too long. The 2017 Concussion in Sport consensus statement reads: "there is insufficient evidence that prescribing complete rest promotes recovery from concussion" and recommends a period of 24–48 h of relative physical and cognitive rest after a concussion [3••]. The Centers for Disease Control and Prevention guidelines for management of mild traumatic brain injury (mTBI) in children echo these recommendations and state that there is limited scientific evidence to support the timing, duration, and efficacy of rest [21••]. They recommend several days of "more restrictive cognitive and physical activity" after which patients should begin a gradual return to learn and return to physical activity program.

Return to Learn/Work

Concussion symptoms can be categorized into four main domains: autonomic, vestibular-ocular, cognitive, and mood (Table 1) [22]. Concussed individuals usually have symptoms in more than one domain, and symptoms in one domain can exacerbate another. For example, physical symptoms may exacerbate cognitive/mood symptoms, and vice versa, so it is important to diligently address each domain.

Deficits in each of these domains can negatively impact successful reintegration into school and/or work. When a clinician is determining the practicality of returning to cognitive activity, each domain should be assessed while taking the history and performing a physical exam of a concussed patient [22, 23].

The evaluation of the vestibular-ocular system warrants particular emphasis here as vestibular-ocular deficits are generally exacerbated by the constant eye tracking required in school or at work. The initial exam includes balance testing, which can be performed by observing tandem gait and sway, or by using the balance error scoring system (BESS), which includes double leg stance, single leg stance, and tandem stance. In addition to balance impairment, the other most recognizable deficits on physical examination are horizontal saccades, vertical saccades, and near-point convergence [22]. Horizontal saccade impairment usually will impart difficulty with reading due to difficulty tracking across a page. Vertical

Table 1 Symptom domains in concussion

Autonomic	Vestibular-ocular	Cognitive	Mood
Headaches	Convergence insufficiency	Shorter attention span	Irritability
Photophobia	Accommodation deficits	Memory difficulties	Anxiety
Phonophobia	Nausea	Impaired processing	Depression
Postural hypotension	Dizziness		Insomnia

saccade impairment makes scanning from top to bottom of a page and looking up and down at a blackboard challenging and symptom provoking. Convergence insufficiency impairs the ability to easily transition from a distance to something close, such as reading a textbook or blackboard and then taking notes on a paper. In a brief VOMS exam, these deficits can be elicited and can guide return to learn/work accommodations (Table 2) [23–25].

Most concussed students require only temporary, short-term accommodations and will return to a normal workload within several weeks. Formal accommodations such as an individualized education plan (IEP) or 504 plan are not usually needed. There are various short-term accommodations that correspond to the various symptom domains. For vestibular-ocular deficits, accommodations in an academic setting might include attending class and paying attention without taking notes, preprinted notes provided by the teacher or classmate, and/or use of enlarged fonts (zoom feature on computer, enlarged on photocopy) or audiobooks. For cognitive difficulties, accommodations may help adjust for a student's post-injury poor attention span, memory problems, and slower processing speed. Decreased course load is the first choice, with preference for missing courses that do not build on prior topics. For example, math, science, or foreign languages are courses that should ideally not be skipped because the student will not be able to jump ahead without first mastering the concepts they missed [22]. Students should be given extra time to complete assignments, delay test-taking as needed, and skip nonessential work. Students should not be penalized for inability to complete work according to a rigid timeline as that only further adds to anxiety and contributes to problems in the mood domain. Clinicians should provide detailed accommodation letters for their students and be willing to advocate on behalf of the student to their school counselor for assistance in implementing those accommodations [24].

Table 2 Overview of brief VOMS examination

Examination maneuver	Physical examination findings
Smooth pursuits	1) Nystagmus with tracking: yes or no 2) Can track fast moving objects: yes or no 3) Record number of repetitions
Saccades	1) Vertical – symptoms: yes or no a. Number of repetitions before symptoms 2) Horizontal – symptoms: yes or no a. Number of repetitions before symptoms
VOR/gaze stability	1) Vertical – symptoms: yes or no a. Number of repetitions before symptoms 2) Horizontal – symptoms: yes or no a. Number of repetitions before symptoms
Visual motion sensitivity	1) Symptoms – yes or no and document number of repetitions
Near point convergence (binocular)	1) Adults: Is it less than 10 cm? 2) Adolescents and children: Is it less than 6 cm?
Balance	Numerous ways to test balance 1) Tandem walk: forward eyes open and closed, backwards eye open and closed 2) Balance Error Scoring System 3) Sway – digital app testing

Gradual Return to Play

The most recent Concussion in Sport consensus paper recommends that after a brief period of rest (24–48 h), the athlete follow a gradual return to sport protocol of six stages. Stage 1, "symptom-limited activity," involves the athlete reintroducing daily activities that do not make concussion symptoms worse. In stage 2, "light aerobic exercise," the athlete performs noncontact cardiovascular activity such as walking or stationary cycling at low to medium intensity to increase heart rate. In stage 3, "sport-specific exercise," the athlete performs sport-specific drills such as sprinting or throwing or batting off of a tee in order to add movement. In stage 4, "non-contact training drills," the athlete participates in harder training drills and may start weight training in order to build fitness and coordination. There should be a minimum of 24 h between each stage. However, this minimum should be individualized based upon the provider's evaluation. If symptoms worsen during a stage, the athlete should wait until symptoms return to baseline and then go back to the previously tolerated stage and repeat before attempting to progress. Upon successful completion of stages 1–4 and upon resolution of concussion symptoms, the athlete may be cleared to progress to stage 5 (full-contact practice) and, if asymptomatic with stage 5, then they may be cleared for stage 6 (full-contact game/activity) [3••].

Safety of Exercise Post-Concussion

Similar to the pendulum swing that has occurred with respect to cognitive rest in concussion management, whereby we are now recommending patients return to some cognitive activity within 1–2 days post-injury as long as it does not exacerbate symptoms, the pendulum is also swinging with regard to physical activity post-injury. While the 2012 Concussion in Sport group recommended no return to physical activity until resolution of concussion symptoms [4], this concept of resting from physical activity until symptom-free has been challenged by updated science. The Buffalo Concussion Treadmill Test (BCTT) was developed as a way to standardize the evaluation of exercise tolerance after concussion, and determine the "threshold" at which symptoms are exacerbated. The BCTT gradually increases grade from 0 to 15 degrees followed by increasing speed at 1 mph every 2.5 min from a starting speed of 3 mph. Symptom severity, perceived exertion, and heart rate are recorded until symptom exacerbation or voluntary exhaustion [26]. This data is used to establish the submaximal symptom threshold and exercise is prescribed at an intensity of 80–90% of the threshold HR (HR at which symptoms were provoked). The Buffalo Concussion Bike Test (BCBT) may be used in a similar fashion if the treadmill is not appropriate for a given patient [27]. This test is safe to use in the evaluation of exercise tolerance in the acutely concussed athlete [28].

Does Exercise Expedite Recovery?

Several studies have shown an association between early physical activity and decreased duration of post-concussive symptoms [19, 20]. A recent study looked at the effect of prescribed subthreshold aerobic exercise vs relative rest (no structured exercise) on the rate of symptomatic recovery in 54 adolescent high school athletes who were referred to concussion clinics within 10 days after SRC. The relative rest group was a historical cohort, given that prescribed rest is not the current standard of care. Recovery time was significantly shorter in the exercise group and none of the patients in the exercise group experienced prolonged symptoms. While acknowledging the limitations of the lack of randomization, that the rest group was not strictly monitored, and that the study population was limited to adolescent males, the authors conclude that prescribed subthreshold aerobic exercise may facilitate recovery and have a beneficial effect on concussion physiology [29]. These results are promising in steering acute treatment following sports-related concussion towards early active subthreshold aerobic activity.

Emerging Treatment Areas

Reassurance and Anticipatory Guidance

Reassurance and anticipatory guidance provided at the time of injury or soon thereafter can improve outcomes in concussion care. The CDC recommends that health care providers counsel patients and families "that most (70–80%) of children with mTBI do not show significant difficulties that last more than 1–3 months after injury" [21••]. In a study of 61 children with mTBI, those who had an office visit and who were given an information booklet that discussed symptoms and management of mTBI had fewer symptoms at 3 months post-injury compared to mTBI patients evaluated at 3 months post-injury who did not have the 1-week visit nor any anticipatory guidance provided [30]. A follow-up study performed on adults showed similar results: adults post-mTBI who received a follow-up visit and information booklet 1 week post-injury had lower symptom scores at 3 months compared to those who did not have the 1-week post-injury visit nor educational booklet [31].

Medication

Up to 90% of clinicians who treat SRC recommend over the counter or prescription medications for patients presenting with acute concussion [32–34]. In the first 48 h post-concussion, a survey of sports medicine physicians indicated that the most commonly recommended medications were acetaminophen (98%), ibuprofen or other NSAID (35%), or melatonin (11%). After 48 h post-concussion, the medications most commonly recommended were acetaminophen (90%), ibuprofen or other NSAID (60%), amitriptyline (46%), and melatonin (43%) [32].

Though medications are commonly recommended by clinicians in the acute post-concussion period, there are no FDA-approved medications for the indication of acute sports concussion. The majority of medications used clinically are aimed at treating post-traumatic headaches which often share features with tension and migraine headaches [35]. Clinicians tend to use the FDA-approved abortive and preventive medications for migraine in the treatment of post-traumatic headache. The effects of this medication use in the acutely post-concussive period are unknown. Pharmacologic interventions have not been shown to expedite recovery from sports-related concussion [36]. The CDC recommends that, for children with acute concussion, over the counter ibuprofen and/or acetaminophen be offered as needed for headache. A main complication from pharmacologic treatment for post-traumatic headache is medication overuse headache. Medication overuse headache is defined as follows: (1) Headache occurring 15 days or more in a month in a patient with a pre-existing headache disorder and (2) regular use (≥ 10 days per month for >3 months) of ergotamines, triptans, opioids, or some combination or regular use (≥ 15 days per month for >3 months) of acetaminophen or nonsteroidal anti-inflammatory drugs [37]. Because medication overuse headache is such a frequent factor in chronic post-traumatic headache in children, parents should be counseled about this risk [21••, 38].

Omega-3 Fatty Acids

Frequently, patients and their families are interested in the utility of supplements in the treatment of acute sports-related concussion. There is more literature pertaining to the use of supplements in the treatment of post-concussion syndrome compared to supplement use in the treatment of acute concussion. Here, we will focus on the body of work studying omega-3 fatty acids and their potential use in preventing and treating acute TBI.

There are three types of omega-3 fatty acids used by the human body: alpha-linolenic acid, found in plant oils, and eicosapentaenoic acid and docosahexaenoic acid (DHA), found in marine oils. The majority of omega-3 fatty acid in the brain is DHA. DHA-phospholipids are a main ingredient in central nervous system membranes. Changing the DHA composition of membranes can affect brain function including axonal and dendritic stability, neuronal plasticity, glucose uptake, neuroinflammation, and hypothalamic function [39].

TBI reduces DHA in the brain in animal models [40]. Following TBI, animals whose brains were deficient in DHA showed more signs of injury and recovered more slowly than those replete in DHA [41]. Animals post-TBI who were given a DHA-containing supplement that was designed to promote synthesis of phospholipids, and thus, aid in membrane recovery, had improved cognitive and sensorimotor outcomes compared to controls [42].

Because of the promising data showing that omega-3 fatty acids can expedite recovery post-TBI, there is increasing interest in the potential benefit of omega-3s in recovery from mTBI. Salberg et al. studied the use of a supplement containing resveratrol (a polyphenol found in grapes that has been shown to decrease neuronal damage and decrease oxygen free radicals in the brain postTBI), prebiotic fiber (a nondigestible carbohydrate that promotes the growth of beneficial gut bacteria involved in the signaling network between the central nervous system and enteric nervous system), and DHA in the prevention and treatment of mTBI in rats. Compared to the controls, rats given the supplement containing resveratrol, prebiotic fiber, and omega-3 fatty acids had improved function post-mTBI and fewer longer term deficits [43]. To date, there are no published studies on the use of omega-3 supplementation to treat mTBI in humans; however, there are three randomized controlled trials underway [44–46]. As of August 2014, the FDA did not recommend the use of any supplements to treat concussion [47].

Sleep

Post-TBI, up to 50% of patients report disrupted sleep while up to 30% develop a sleep disorder [48]. Poor sleep is associated with increased concussion symptom burden, greater psychological distress, and poorer functional and social outcomes after mild TBI [49, 50]. TBI patients with sleep disturbance during the acute (< 3 months) period were found to have increased depression, anxiety, and apathy at 1 year [51].

There is a growing interest in treating sleep disturbance post-TBI in order to improve outcomes. Investigations include the use of hyperbaric oxygen in US veterans with post-concussion syndrome after mild TBI [52], treatment of sleep disturbance after mild–severe TBI with prolonged-release melatonin [53], and cognitive behavioral therapy for patients with TBI and chronic sleep disturbance [54].

There are limitations to using these studies to apply to the acutely concussed athlete. First, the majority of studies published to date include patients with a full spectrum of TBI, from mild to severe. Secondly, the majority of studies evaluate treatment for patients with post-concussion syndrome, at least 3 months post-injury. Further work should be done to evaluate the effect of treatment of sleep disturbance in the acute post-concussion period (< 3 months) on recovery time after mTBI.

Physical Therapy

Similar to the body of work investigating sleep optimization and recovery from TBI, the literature evaluating physical therapy's utility post-SRC has focused on patients with persistent post-concussion symptoms. A recent systematic review found moderate evidence that physical therapy for patients with persistent neck problems and/or vestibular-ocular problems post-concussion can hasten recovery. There is a need for more information about whether or not physical therapy expedites recovery for patients presenting acutely with neck pain, dizziness, and headaches [36].

Conclusions

The treatment of acute SRC should include immediate cessation of sport followed by relative cognitive and physical rest in the 24–48 h immediately following concussion. Patients and families benefit from reassurance and anticipatory guidance during this time. After this brief period of rest, symptom-limited gradual return to cognitive and physical activity is recommended. There is no evidence that complete cognitive and physical rest nor prolonged cognitive and physical rest expedites recovery from SRC. Several accommodations can be made to facilitate earlier return to learn or work. These accommodations should be individualized to the patient and based on the patient's history and physical exam with particular attention to the patient's vestibular-ocular system. Some evidence suggests that early, symptom-limited exercise may expedite recovery from concussion. The BCTT can help determine a submaximal symptom threshold to define an appropriate exercise dose. Early subthreshold aerobic activity shows promise in reducing prolonged post-concussive symptoms, potentially speeding up recovery and minimizing time lost in sport. Further research on the utility of supplements, medications, and sleep optimization and treatment of neck pain and vestibular-ocular dysfunction with physical therapy could potentially contribute to current management strategies for acute SRC.

Compliance with Ethical Standards

Conflict of Interest Anjali Gupta and Greg Summerville each declare no potential conflicts of interest.

Carlin Senter is a section editor for *Current Reviews in Musculoskeletal Medicine Medicine*.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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