Current and Emerging Rehabilitation for Concussion: A Review of the Evidence

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KEYWORDS

• Concussion • Physical rest • Cognitive rest • Vestibular rehabilitation
• Pharmacologic interventions

KEY POINTS

- Concussion rehabilitation policies are largely consensus based.
- Emerging evidence is suggesting that exercise and cognitive activity in a controlled and prescriptive manner may benefit recovery.
- Additional rehabilitation strategies (eg, vestibular, oculomotor, and pharmacologic) also have mounting evidence and should be incorporated by an appropriately trained professional when appropriate.

INTRODUCTION

The clinical signs and symptoms of sport concussion have long been recognized as[1,2] brought about by an extrinsic force applied directly or indirectly to the head or body.[3] Much of the scientific literature surrounding this injury has focused on injury incidence,[4] assessment tools,[5,6] and recovery patterns among athletes.[7] Absent from the literature are reviews of empirical studies assessing the effectiveness of different rehabilitation approaches for concussed patients. Therefore, this article reviews and evaluates the evidence supporting consensus-based standard of care (eg, physical and cognitive rest) and emerging, targeted (eg, vestibular, oculomotor, exertional, pharmacologic) rehabilitation approaches for concussion based on an evolving model of clinical concussion care.[8]

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Clin Sports Med 34 (2015) 213–231
http://dx.doi.org/10.1016/j.csm.2014.12.005 sportsmed.theclinics.com
0278-5919/15/$ – see front matter

The concept of physical and cognitive rest as the cornerstone of concussion management was developed by the International Concussion in Sport Group and currently states, "The cornerstone of concussion management is physical and cognitive rest until the acute symptoms resolve and then a graded program of exertion prior to medical clearance and return to play."[3] The rationale for rest asserts that during the acute (1–7 days, possibly longer in youth) postinjury period of increased metabolic demand and limited adenosine triphosphate reserves, nonessential activity draws oxygen and glycogen away from injured neurons. The Concussion in Sport Group recommendation has been interpreted by many clinicians to mean that all concussed athletes should be restricted from all physical and cognitive activity until symptoms resolve, at which point, the athlete could be cleared to begin a return to play progression. This "shut-down" or "dark-closet" approach following concussion is wrought with potential pitfalls for patients, including hyperawareness of symptoms, somatization, social isolation, and other potential comorbid concerns. Citing the risk for prolonged and exacerbated symptoms that may not be directly related to the concussive injury, other medical organizations have recommended that athletes be permitted to engage in limited physical and cognitive activity so long as it does not worsen symptoms.[9]

These 2 perspectives regarding strict rest versus physical and cognitive activity as tolerated are seemingly at odds with each other, in part because there is no agreed on definition of what constitutes rest following a concussion in the literature. Such recommendations are also limited because they do not take into account the individualized nature of the injury, potential risk factors that may influence outcomes, and differential responses to recovery. Moreover, and most importantly, there are no known prospective randomized control trials (RCTs) evaluating rest in concussed athletes immediately following a concussion.[10] In fact, the evidence for physical and cognitive rest is limited, relying on observational studies and studies of patients from sports medicine clinics during the subacute stage.[11,12] With a dearth of literature to support clinical guidelines, expert consensus has been used in its place.

The premise that rest is the most effective management strategy for all concussed patients assumes that all concussions are alike, yet concussion recovery is known to be influenced by several modifying factors including sex,[13] concussion history,[14] and age.[15] Even for injuries occurring within these populations, concussions manifest in varied symptoms (eg, headache, dizziness, fogginess), cognitive (eg, memory, reaction time, processing speed),[16] psychological (eg, depression, anxiety),[16] and vestibular (eg, dizziness, imbalance, gait, vestibulo-ocular)[17] impairments. As such, this highly individualized injury results in a varied injury presentation, indicating no single rehabilitation strategy will be effective for all patients following concussion necessitating distinct treatment.[8]

PHYSICAL REST

Declines in neurocognitive function and motor control and increases in self-report symptoms following concussion are well documented.[5,18] Among the most commonly reported symptoms are headache, dizziness, and confusion immediately following a concussion.[19–25] Other research has reported increased rates of depression and fatigue among the same cohort.[26] Between 80% and 90% of concussed individuals will return to preinjury levels of functioning within 2 weeks without intervention, but a small percentage (2.5%) will remain symptomatic 45 days after injury, despite resolution of other objective measures (eg, neurocognitive and balance assessments).[27] Therefore, management of athletes falling within and outside the range of normal recovery may require different approaches.

Evidence for Physical Rest

Consensus supporting physical rest recommendations is partly predicated on risk management and animal studies demonstrating impaired recovery with the early onset of physical activity. Although secondary to restricting activity to facilitate recovery, restricting physical activity to reduce risk for a second injury has broad support as the sole means to eliminate Second Impact Syndrome.[28] Even in the absence of a catastrophic outcome, animal models show metabolic dysfunction in the days immediately following injury[1,29] with an increased energy demand within the cerebral tissue as ion imbalances are returned to preinjury levels. During this time, the risk for second injury seems to be highest[23] and an additional injury sustained shortly after the first increases recovery time and impairs the ability to learn among rodents.[30] Similar metabolic dysfunction findings among concussed athletes were reported by Vagnozzi and colleagues.[31] That is, altered cerebral metabolism lasting up to 30 days was documented using magnetic resonance spectroscopy imaging in concussed athletes and up to 45 days in those sustaining a second injury before resolution of the first.[32]

In addition, subsequent injury risk and prolonged recovery brought about by sport participation, unrestricted physical activity in a controlled and safe environment during the acute recovery stage, may be detrimental. For example, rats exposed to a fluid percussion injury and provided unrestricted running wheel access within the first 6 days of injury showed poorer performance on a cognitive task (ie, Morris water maze) compared with similarly injured rats that were restricted from activity until day 14 after injury.[33] In addition, a review of medical records from 159 concussed patients found that those returning to play before concussion symptom resolution reported worsening concussion-related symptoms.[34] The mechanistic underpinnings explaining these findings are not entirely clear, but it is possible that early exercise may draw energy (ie, glycogen) away from the brain and inhibit the recovery process.

Evidence for Physical Activity

The evidence supporting physical activity following concussion is sparse, but other medical literature suggests that withholding injured, but nonconcussed athletes from exercise increases reports of depression, anxiety, and lower self-esteem when evaluated both at the time of injury and 8 weeks later.[35] Injured (nonconcussed) high school athletes missing a minimum of 3 weeks of athletic participation also showed higher rates of depression than noninjured athletes. The authors indicated that high levels of athletic identity partly explained the finding.[36] Moreover, onset of migraine has been shown to occur in patients with limited or minimal physical activity.[37] Ultimately, removing an athlete from sport may increase the risk for depression and other concussionlike symptoms to develop, yet the point at which an athlete can begin physical activity following concussion is unclear.

In the single human study evaluating exercise shortly after concussion, 95 concussed student-athletes retrospectively self-reported physical and cognitive activity in the 30 days following injury and compared the findings to a neurocognitive assessment. Each athlete was categorized into 1 of 5 groups ranging from “no school or exercise activity” to “school activity and participation in sports games” and completed a computerized neurocognitive assessment for both cognitive functioning and self-report symptoms. The results indicated that athletes engaging in a medium level of physical and cognitive activity (ie, school activity and light activity at home, such as slow jogging or mowing the lawn) performed better on the neurocognitive test than those with no physical and cognitive activity and those reporting the highest levels of physical and cognitive activity.[38] These findings should be cautiously interpreted however, because the physical and cognitive activity was self-report recall by the injured athlete. In addition, it is not known at what point after the injury the athletes elected to begin physical activity. Coupled with the previously discussed animal work, this investigation set the groundwork to suggest that unrestricted exercise in the immediate acute phase of concussion recovery may increase the risk of subsequent injury and/or delay recovery, yet some level of exercise may be beneficial to the recovery process once the athlete has moved beyond the acute injury stage.

When dealing with athletes continuing to experience concussion-like symptoms beyond the acute injury stage, stronger literature is available showing the benefit of physical activity as a means to mitigate symptom reports. Leddy and colleagues[39] implemented a graded return to activity protocol on 6 concussed athletes that had been symptomatic for a minimum of 6 weeks (mean 19 weeks) following a concussive event. Once enrolled, the athletes were monitored for an additional 2 weeks, wherein there was no change in their symptom reports. They then began an exercise protocol 5 to 6 days a week with intensity monitored by heart rate. After 6 weeks of the intervention, the athletes had a significant decrease in their symptom reports and were able to return to sport. Interestingly, a concussed nonathlete group completed an identical protocol, but did not show the same decline in symptom reports as the athlete cohort. A follow-up investigation enrolled 91 participants that had been experiencing symptoms following a concussion for a minimum of 3 weeks. Each participant completed a baseline graded exercise test, whereby 26 were able to reach maximum exertion. These individuals were determined to be experiencing symptoms related to something other than concussion, whereas 35 of the remaining 65 continued with the same heart rate–based exercise protocol described above. A return to full functioning by means of the exercise protocol was achieved in 77% of the subset (n = 27).[40]

Exercise has been proven to be a powerful modality for cognitive health,[41] but the implementation of postconcussion exercise should be carefully considered relative to the time from injury. The limited literature available to date suggests that athletes experiencing symptoms in the acute stage of injury should avoid full sport participation to avoid secondary injury as well as exercise in a controlled environment because it may increase recovery time. Animal and retrospective human studies, however, suggest that athletes continuing to report symptoms beyond the acute stage of injury may benefit from moderate levels of exercise. Last, those athletes that continue to report concussion-related symptoms well beyond the acute stage of injury may benefit from a progressively intensive exercise protocol to return them to their sport.

COGNITIVE REST AND ACADEMIC ACCOMMODATIONS

Cognitive impairment following concussion is common among student-athletes and cognitive rest has been suggested to enhance recovery. The cognitive rest theory is based on the premise that increasing cognitive activities following concussion will increase symptom recovery time and prolong recovery. Cognitive rest includes the reduction of brain stimulating activities (eg, television, video games, school work, reading, and writing) and, despite the limited data to support the use of cognitive rest, it is widely recommended in consensus statements and concussion guidelines.[3,9,42–45]

To date, few studies have evaluated cognitive rest; however, these studies have found that increased cognitive activity does delay symptom recovery. Moser and colleagues[11] studied 49 high school and collegiate athletes prescribed a minimum of a week of cognitive and physical rest. Both before and after rest periods, individuals performed the ImPACT and cognitive testing measures. The study concluded with a period of cognitive and physical rest with individuals showing increased performance on the ImPACT and cognitive testing as well as decreased symptom reporting. Similarly, Brown and colleagues[12] studied 335 patients (mean age, 15 years) on level of cognitive activities between clinical visits, finding that longer concussion recovery time was related to higher cognitive activity levels. Indeed, those participating in the lowest 50% of cognitive activity were completely asymptomatic within 100 to 150 days of injury, whereas those engaging in the third and fourth quartiles of cognitive active took up to 300 and 500 days to recover, respectively.

School is a major component of a student's life, requiring the attainment of new knowledge, development of academic skills, and diligent work to complete assignments and prepare for examinations. To be successful in academic endeavors, students must engage in classroom learning requiring attention, material memory recall, critical thinking, and problem-solving. Students who sustain a sports-related concussion (SRC) may also experience physical, mental, behavioral, and social changes that impact their daily life and threaten their ability to learn and succeed academically.[46] Limiting school activity is one mechanism that affords the injured athlete time to mitigate concussion-related symptoms.

Despite limited research on cognitive load following concussion, it has been suggested that some concussed students may benefit from excused or reduced academics (eg, classroom attendance, homework, examinations) immediately following injury.[47–49] Returning to academic work while symptomatic may cause symptoms to worsen, resulting in a decline in academic performance.[48,50] Although there are more formal accommodations available for long-term or prolonged cases, temporary and targeted accommodations during the acute recovery time is an easy tool to assist a student's return to the classroom.[47] Temporary accommodations may include, but are not limited to, excused absences, lighter homework, breaks during the day, starting later or ending the school day earlier, and extended examination or homework dates.[49] Once the athlete no longer reports concussion-related symptoms, a transition period to partial and then full days is recommended.[51]

Requiring a student-athlete to attend school immediately following a concussion may place him or her in a compromised academic position. Concussed student-athletes engaging in moderate to intense cognitive activity may exacerbate symptoms,[12] resulting in incomplete school work, making excused absences important to the recovery process. During this period, a time extension to complete academic assignments including homework and examinations allows the student-athlete to make up missed schoolwork and take their time with completion of assignments. Implementing delayed testing or project due dates can help the student maintain good academic standing without the penalty of decreased scores. Temporary accommodations such as these are commonly implemented quickly and without burdensome paperwork. To ensure these tools are available, the concussion management team should prearrange their use with school personnel as part of the concussion management plan before the athletic season.

Those individuals experiencing a prolonged concussion recovery or those with recurrent injuries may need additional testing to better accommodate or intervene with school as needed.[51] In some cases, implementing an individualized academic plan can help with the management of accommodations. If a student-athlete is having symptoms or displays challenges greater than 3 weeks, a 504 Plan may be implemented.[47] A 504 Plan refers to the proper section of the Rehabilitation Act that provides medical need accommodations. In order for formal accommodations to be implemented, the student would have to display mental impairments that limit greater than one major life activity.[52] Clinicians may also consider an Individualized Education

Plan (IEP) for those with prolonged concussion recovery. An IEP allows for the school personnel to collaborate with the physician, student-athlete, and parents to create a plan that will best help that student receive special education.[53] Both IEPs and 504 Plans require extensive medical documentation and are a more permanent measure that are embedded into the school system documents, but allow for changes to the student-athlete's academic plan for classroom success.

Despite consensus for cognitive rest, it is important to note that prolonged cognitive rest and reduction of school events have the potential to exacerbate symptoms or cause negative mental health issues. Depression, behavioral issues, and social issues have been shown to increase following a concussion as well as many other injuries when the student-athlete is eliminated from team activities, school events, and social outings.[54] Decreasing school attendance and other social activities can negatively impact some student-athletes and prevent them from going through proper injury-coping mechanisms. Decreased school attendance can also add an increased burden and sense of anxiety to the student-athlete because they are not attending school nor completing school assignments. The mental image of being behind in academics can create a highly anxious environment for student-athletes, especially those who already place high priority on increased academic achievement. Ultimately, the medical team, in conjunction with a trained professional, should balance the neurocognitive and behavioral accommodations of the concussed student-athlete in a way that restricts cognitive activities that trigger or introduce symptom exacerbation, but allow for him or her to become involved in school activities again.

VESTIBULAR AND OCULOMOTOR REHABILITATION

In a new clinical model of SRC care, researchers have suggested that oculomotor and vestibular symptoms and impairment may constitute unique clinical subtypes of SRC—along with cognitive fatigue, anxiety-mood, cervical, and posttraumatic migraine (PTM).[8] These clinical subtypes of concussion, which can occur concurrently or independently, require targeted therapies and treatments to be managed most effectively.[8] For example, an athlete with an oculomotor concussion subtype will benefit most from vision and oculomotor-specific therapies. Without such targeted intervention strategies, an athlete may experience an unnecessarily prolonged recovery from SRC. In a prospective study of recovery times following SRC, researchers reported that 17% of athletes experience prolonged recovery lasting greater than 3 weeks.[55] The identification of specific clinical subtypes of concussion together with the application of targeted treatments and rehabilitation strategies will yield the best clinical outcomes for athletes with SRC. Two clinical subtypes that have been associated with poor clinical outcomes, but that may be amenable to rehabilitation and treatment interventions, are vestibular and oculomotor.

Vestibular and Oculomotor Impairment and Symptoms

Vestibular and oculomotor impairment and symptoms occur in approximately 60% of athletes following SRC.[17] The vestibular system plays an integral role in balance function and in maintaining visual and spatial orientation. Sensory information from each inner ear is used to inform the adjustment of eye movements for clear, stable vision and to adjust muscle reactions of the head and body for balance and gait. Vestibular impairment and dysfunction may involve either the peripheral or the central structures of the vestibulospinal system and may result in disequilibrium and impaired balance.[56] In contrast, dizziness, vertigo, blurred/unstable vision, discomfort in busy environments, and nausea often occur with disruption to the vestibulo-ocular system.[56]

Vestibular symptoms at the time of injury may predict prolonged recovery following SRC. In fact, Lau and colleagues[25] reported that on-field dizziness was the only significant predictor of a prolonged recovery (>21 days) following SRC. This expression of post-SRC dizziness acutely may be the result of disruption to the vestibulo-ocular and gaze stability systems at the time of the injury.

Similar to vestibular dysfunction, impairment in oculomotor control and visual dysfunction are observed frequently following SRC.[57–61] Ciuffreda and colleagues[62] indicated that visual dysfunction involving accommodation, version and vergence, strabismus, and cranial nerve palsy occurred following mild traumatic brain injury (mTBI). Symptoms attributed to poor oculomotor function may include blurred vision, diplopia, difficulty reading, eyestrain, headache, reading difficulties, and problems with visual scanning. Vestibular and oculomotor impairment and symptoms are prevalent following SRC and may play a role in prolonged recovery and related clinical outcomes. Therefore, vestibular rehabilitation and vision therapy interventions are presented and discussed that can be used with athletes experiencing vestibular and oculomotor impairment and symptoms following SRC.

Vestibular Rehabilitation Interventions

There are many different types of vestibular rehabilitation interventions that may be implemented to mitigate vestibular symptoms and dysfunction following SRC. Among the most common vestibular issues following SRC are benign paroxysmal positional vertigo (BPPV), vestibulo-ocular reflex (VOR) impairment, visual motion sensitivity, balance dysfunction, cervicogenic dizziness, and exercise-induced dizziness. **Table 1** summarizes these and other vestibular problems along with targeted therapeutic interventions. It is important to note that these interventions should be performed by licensed physical therapists specializing in vestibular rehabilitation.

Benign paroxysmal positional vertigo is the most common disorder of the vestibular system and can occur posttraumatically after SRC. In BPPV, small calcium carbonate crystals (otoconia), which are normally housed in the otolith organs of the inner ear, become dislodged and relocate to one or more of the adjacent semicircular canals. With head movement in the plane of the affected semicircular canal, the otoconia shift position and create a false excitatory stimulus and resultant vertigo. Reproduction of vertigo and a characteristic nystagmus pattern during positional testing (Dix-Hallpike and Roll Test) are necessary to diagnose BPPV. Canalith repositioning maneuvers, designed to shift the displaced otoconia out of the affected semicircular canal, is the treatment of choice for BPPV.[63]

Gaze stability refers to the ability to maintain visual focus while the head is moving. Although gaze stability is mediated by different vestibular and ocular motor systems depending on the velocity and context of the task, the VOR is the primary mechanism for maintaining eye position during head movement. The VOR is a fast-acting reflex that keeps the eyes stable by generating ocular movements precisely in proportion, but opposite in direction, from the head motion. In sport, where rapid acceleration and high-velocity movement necessitate quick visual responses, intact VOR functioning is particularly important. When the VOR is impaired, visual blurring, dizziness, poor visual focus, and oscillopsia may occur with head motion. The responses of the VOR can be adapted through exercise designed to induce movement of a visual image on the retina. This motion, inducing retinal slip, is the primary error signal that drives adaptation of the VOR. Thus, vestibular physical therapy exercises for VOR adaptation require patients to maintain visual focus on a target while moving their head. VOR adaptation exercises are manipulated in multiple ways to gain maximal benefit,

Table 1
Common interventions for vestibular impairment following sport-related concussion

Impairment	Cause	Symptoms	Associated Problems/Risk Factors	Physical Therapy Treatment
Benign paroxysmal positional vertigo[63]	Mechanical disruption in the vestibular labyrinth (end organ). Otoconia from otoliths become dislodged and displace in semicircular canal	Vertigo with changes in head position	Older age High impact forces	Canalith repositioning maneuvers
VOR impairment[80]	Disrupted function in the VOR pathways, peripherally or centrally	Dizziness	Labyrinthine concussion	Gaze stability training
Visual motion sensitivity[90]	Impaired central processing/ integration of vestibular information with visual and other sensory information	Dizziness	Posttraumatic migraine Anxiety	Graded exposure to visually stimulating environments Virtual reality Optokinetic stimulation
Impaired postural control[91]	Disruption/damage to vestibular-spinal reflex pathways, peripherally or centrally	Impaired balance, particularly with: • Vision and/or somatosensation reduced • Cognitive dual/task demand	Common early finding after concussion; typically resolves before other vestibular deficits	Balance rehabilitation strategies Sensory organization training Divided attention training Dynamic balance training
Cervicogenic dizziness[92,93]	Cervical injury results in abnormal afferent input to CNS; mismatch with other sensory information	Dizziness, related to cervical movement/posture Imbalance Impaired oculomotor control	Cervical pathologic abnormality Cervicogenic headaches	Manual therapy for cervical spine Balance training Oculomotor training
Exercise-induced dizziness[94]	Inadequate central response to cardiovascular and vestibular/ocular demands of exercise	Dizziness with movement-related cardiovascular exercise	• VOR/gaze stability impairment • Visual motion sensitivity • Autonomic dysregulation	Progressive dynamic exertion exercise program

including varying target size and complexity, postures, duration, direction, amplitude, and velocity.

Visual motion sensitivity refers to an increased sense of disorientation, dizziness, or postural instability in situations with visual and vestibular conflict. It is thought to arise from inability of the central nervous system (CNS) to effectively integrate sensory information, particularly vestibular information, creating overreliance on vision. Patients with visual motion sensitivity become particularly symptomatic when exposed to visually disorienting stimuli or environments, such as malls, grocery stores, or even busy patterns. Visual motion sensitivity has also been described as “visual vertigo,” “space and motion discomfort,” and “visual vestibular mismatch” in the literature. Visual motion sensitivity has been reported in patients following peripheral vestibular disorders[64] and in those with migraine[65] and anxiety.[66] It has also recently been recognized in patients following SRC.[17] Treatment of visual motion sensitivity involves gradual and systematic exposure to provocative stimuli to habituate the abnormal responses. Because treatment of visual motion sensitivity has the potential to exacerbate symptoms from concussion, intervention should be introduced in a step-by-step progression that is carefully monitored by a trained vestibular therapist.

Restoring postural control, or balance, is an area of focus for vestibular rehabilitation following SRC.[67–69] Because sensory organization is often impaired[70,71] early after concussion, training the ability to effectively alternate between using visual, somatosensory, and vestibular information for postural control is a key component of balance retraining. Graded exercises for sensory organization deficits involve manipulation of these 3 sensory systems. Examples of sensory organization training activities include performing tasks with eyes closed, while turning the head, with narrowed base of support, on an uneven or soft surface. In addition to sensory organization issues, several studies have shown patients following mTBI have greater difficulty maintaining balance under conditions of divided attention.[72–74] Therefore, dual task condition practice and dynamic balance activities may also be incorporated into vestibular rehabilitation.

Although dizziness is most often attributed to vestibular system dysfunction, it may also arise from other impairment following SRC, which may be responsive to intervention. In cervicogenic dizziness, pathologic abnormality in the cervical spine creates abnormal muscle activity in the deep layers of the upper cervical spine responsible for providing proprioceptive input to the CNS. Dizziness is thought to occur because of the mismatch between aberrant cervical proprioceptive information in relation to vestibular and visual inputs. Because this cervical afferent information also participates in reflex activity for postural control and eye movements, imbalance and impaired eye movements may occur in addition to dizziness. Management of cervicogenic dizziness is directed toward therapies that treat the underlying cervical spine injury to normalize proprioceptive input with visual and vestibular information, along with treatment of any additional balance or oculomotor impairment through targeted exercises (Treleaven 2011).

Last, following concussion, dizziness may arise with exertional activity.[75] In a study of soldiers following blast-related concussion, exercise-induced dizziness was categorized as one type of dizziness typically seen by physical therapists in vestibular rehabilitation. Although there are no studies that confirm the cause of exercise-induced dizziness, the authors postulate that inadequate response of the CNS to combined cardiovascular and vestibular/visual demand may be responsible. Anecdotally, it was found in the authors’ clinic that stationary cardiovascular activities at high levels of exertion (eg, stationary cycling) rarely cause dizziness, whereas cardiovascular activity maintaining similar levels of exertion, when combined with motion (eg, forward/backward line drills), often produces significant levels of dizziness. Clearly, more research is needed to validate this hypothesis. Treatment of individuals with exercise-induced symptoms is controversial; however, preliminary evidence suggests that graded exercise may be useful in modifying these postconcussive symptoms when chronic.[39,76]

The value of vestibular rehabilitation in managing individual vestibular conditions is well documented. A *Cochrane Review*[77] concluded that there is moderate to strong evidence for efficacy of vestibular rehabilitation in improving VOR impairment and balance deficits due to peripheral vestibular dysfunction, and for the use of canalith repositioning maneuvers performed by vestibular therapists in the management of BPPV. Dizziness due to migraine as well as patients with central vestibular dysfunction has been shown in studies to improve with vestibular physical therapy intervention (Whitney and colleagues, 2000; Brown and colleagues, 2006). Therapies for visual motion sensitivity, such as optokinetic stimulus exposure, have been shown to be effective with peripheral vestibular disorders (Pavlou 2013). Several studies have investigated the efficacy of physical therapy treatment of the cervical spine for cervicogenic dizziness (Malmstrom 2007, Heidenreich 2008, Reid 2008), including a recent RCT (Reid 2014) demonstrating significant reduction in intensity and frequency of cervicogenic dizziness with 2 different manual therapy techniques over placebo. Although vestibular therapies have been shown to be beneficial in the treatment of various vestibular-related impairments, the evidence for using vestibular physical therapy for impairment attributed to SRC is limited and consists primarily of retrospective, cross-sectional, and small cohort studies.

A recent study by Schneider and colleagues[78] conducted an RCT with a sample of 12- to 30-year-olds with dizziness, neck pain, and/or headache following SRC. After 8 weekly physical therapy sessions consisting of vestibular and cervical spine rehabilitation, subjects in the treatment group were nearly 4 times more likely to be medically cleared when compared with a control group. In a retrospective chart review, Alsalaheen and colleagues[79] examined the response of a population of concussed patients to vestibular physical therapy. Data from 114 patients referred for vestibular rehabilitation following concussion demonstrated a significant treatment effect for 15 different measures of dizziness severity, balance confidence, gait, and static/dynamic balance. Gottshall and Hoffer[75] assessed computerized VOR and gaze stability measures in 82 military individuals who experienced blast-related mTBI. Impairment was significant at the time of initial evaluation, but returned to normative levels after 4 to 12 weeks of vestibular physical therapy. Hoffer and colleagues[80] examined the effect of vestibular rehabilitation in a population of 58 active duty military individuals with postconcussive dizziness. They found that after a 6- to 8-week vestibular rehabilitation program, patients had improved with respect to symptoms of dizziness, perception of balance function, and measures of VOR function. However, the effectiveness of vestibular rehabilitation differed based on type of posttraumatic dizziness. Specifically, patients with PTM-associated dizziness were most responsive to treatment (84%) in contrast with the spatial disorientation group (27%).

Vision Therapy

Most oculomotor problems following SRC, such as convergence insufficiency, accommodative insufficiency, impaired version movements, and minor ocular misalignments, may be managed conservatively with vision therapy.[57] However, in rare instances, surgical/medical intervention by an ophthalmologist or neuro-ophthalmologist may be warranted for complex diplopia, strabismus that is due to muscle paralysis or nerve palsy, or other concurrent ocular-health issues. Typically, vision therapy involves vision exercises using eye patches, penlights, mirrors, lenses, prisms, and other nonsurgical interventions to improve the function of the ocular muscles.

Despite anecdotal evidence for the effectiveness of vision therapy following SRC, there is limited empirical support for vision therapy in the literature. However, a 2011 *Cochrane Review* of RCTs for nonsurgical intervention for convergence insufficiency, and another RCT by Scheiman and colleagues for treatment of accommodative insufficiency, pointed to the effectiveness of vision therapy in children in managing these 2 conditions.[81,82] Although empirical support for oculomotor and vision-related therapies following SRC is limited and does not include any RCTs, emerging evidence supports the effectiveness of visual exercises for specific oculomotor problems. A retrospective study by Ciuffreda and colleagues[62] examined patients with mTBI who were enrolled in a vision therapy program consisting of combined vergence, version, and accommodative exercises. They reported that 90% of patients improved markedly or completely in symptoms and subjective reports of enhanced reading at a 2 – to –3-month follow-up. In a recent study involving 12 subjects following mTBI, Thiagarajan and Ciuffreda[83] demonstrated that an oculomotor training program targeting the version, vergence, and accommodation components of the ocular motor system significantly improved the amplitudes of vergence and accommodation, accuracy of saccadic eye movements, and overall reading.

PHARMACOLOGIC INTERVENTIONS

It has been reported that as much as 89% of clinicians manage symptoms of athletes with SRC using over-the-counter (OTC) or prescription medications.[84] The most common interventions involve OTC medications such as nonsteroidal anti-inflammatory drugs and acetaminophen. However, many other prescription pharmacologic interventions are used with athletes who are not following a normal recovery trajectory (ie, recovered within 10–14 days) following SRC. Research indicates that pharmacologic treatments usually begin at approximately 10 days after injury.[42] As with vestibular and oculomotor therapies, pharmacologic interventions are most effective when they target specific clinical subtypes of SRC. For example, an athlete with a primary cognitive-fatigue subtype following SRC may be prescribed a neurostimulant such as amantadine. In addition to cognitive fatigue, other clinical subtypes that are amenable to pharmacologic treatment include PTM and anxiety/mood.[3,8] In addition, sleep-related issues are often treated using pharmacologic interventions. It is important to acknowledge that there is still no US Food and Drug Administration–approved pharmacologic treatment for SRC. As such, all pharmacologic interventions discussed later involve off-label use of medications that were approved for other primary purposes. Moreover, each medication discussed may involve side effects that warrant close monitoring from prescribing clinicians. In addition, the use of certain medications, such as neurostimulants, may be in violation of the medication and performance enhancement policies of specific sport governing bodies; thus, proper documentation is very important.

Targeted Pharmacologic Interventions: Matching Treatments to Clinical Subtypes

Cognitive fatigue is a commonly targeted clinical subtype for pharmacologic intervention. Athletes with this subtype experience difficulty concentrating, memory problems, attentional issues, decreased vigor, and headaches that worsen throughout the day. These symptoms are often treated effectively with the use of a neurostimulant. The most commonly used neurostimulant is amantadine, with 10% of clinicians reporting that they prescribe amantadine to athletes following SRC.[84] There is some empirical evidence that amantadine, a dopaminergic neurostimulant primarily purposed as a antiviral medication, can improve cognitive-fatigue symptoms and memory in athletes experiencing prolonged recovery following SRC.[85] Other neurostimulants that can be used to treat athletes with cognitive fatigue include methylphenidate, Adderall, and atomoxetine. There is some evidence of the effectiveness of methylphenidate on improving processing speed in moderate TBI (eg, [86]), but not in athletes with SRC. Of note, some athletes may already be taking these medications for attention deficit hyperactivity disorder and related conditions, thereby necessitating close monitoring from clinicians; medications may need to be adjusted during their recovery period.

Some athletes may develop anxiety or mood issues as a direct result of an SRC or secondary to the injury recovery process with its concomitant frustrations and feelings of isolation and loss of control.[16] Other athletes may have pre-existing anxiety/mood issues before injury that may be exacerbated following an SRC. Regardless of its underlying cause, anxiety and mood issues following SRC can be treated with tricyclic antidepressants (eg, amitriptyline). In fact, tricyclic antidepressants are used by up to 23% of clinicians in treating young athletes with SRC.[84] It is likely that this relatively high percentage of clinicians prescribing tricyclic antidepressants is due in part to its use across multiple clinical subtypes, including anxiety and mood, sleep, and PTM. Other common medications used for athletes in the anxiety and mood clinical subtype include selective serotonin reuptake inhibitors (SSRI) and selective norepinephrine reuptake inhibitors. There is some anecdotal evidence that short-term, low-dosage use of certain benzodiazepines such as Klonopin may be effective in athletes with vestibular-related anxiety. Klonopin and other benzodiapenes are also thought to act on neurons in the vestibular nuclei of the brain to decrease vestibular-related symptoms and in turn decrease anxiety. Klonopin can be effective for vestibular-related migraines. However, Klonopin can result in elevated anxiety and sleep disruption in some athletes and its use should be monitored closely.

The symptoms of PTM include headache, nausea, photo-sensitivity or phonosensitivity, and dizziness. These symptoms have been associated with prolonged recovery and impairment following SRC.[87] Clinicians may use a variety of pharmacologic interventions to treat the symptoms of PTM, including tricyclic and SSRI antidepressants, anticonvulsants (eg, topiramate, gabapentin, valproic acid), or β-blockers. In addition, triptans (eg, Imitrex, Maxalt) are often prescribed as abortive medications for PTM. Despite anecdotal evidence regarding the effectiveness of these treatments, there are no empirical studies of the effectiveness of these medications in athletes with SRC.

There is often a sleep overlay that permeates across each clinical subtype of SRC. Consequently, clinicians often prescribe OTC and prescription sleep medications for athletes with persistent sleep disruptions following SRC. After all, if an athlete is not sleeping well following an SRC, it will be difficult for that athlete to recover. The most commonly used sleep medication is melatonin with one-fifth of clinicians reporting that they prescribe melatonin to athletes with sleep disruptions following SRC.[84] Melatonin together with basic sleep hygiene can help regulate circadian rhythms and promote better sleep-wake cycling.[88,89] Other medications used to improve sleep disruption in athletes following SRC include antidepressants (eg, amitriptyline, trazodone) and nonbenzodiazepine hypnotics (eg, Ambien, Lunesta).[89]

SUMMARY AND RECOMMENDATIONS

Despite limited empirical support, physical and cognitive rest have been deemed essential components of initial concussion management and treatment. Such recommendations have been developed by consensus and introduced by the International Concussion in Sport Group in 2008. Since that time, there has been limited empirical work evaluating the efficacy of physical and cognitive rest protocols. Some research suggests that prescribed physical and cognitive rest in the acute stage of concussion may be of benefit to some athletes. However, other studies have indicated that an early return to light to moderate physical activity may be effective for other athletes following concussion. The heterogeneous nature of concussion renders a universal prescription of strict rest for all concussed athletes an ineffective strategy. As such, strict rest extending beyond the acute injury stage may result in the athlete developing concussionlike symptoms that are unrelated to the injury (eg, anxiety, migraine, sleep disorders) and may complicate injury management, which may in turn lead to psychological and other concurrent problems. Student-athletes who are unable to attend or participate in academics to the fullest may benefit from a reduced cognitive load following injury, with a graduated return to academics that does not exacerbate symptoms. Reduction of cognitive load requires a coordinated effort between the medical and school academic support staff with short-term or long-term academic accommodations. Any accommodations may be lifted once a complete academic schedule can be completed without symptom exacerbation, at which time a return to play protocol be undertaken.

Sport-related concussions can involve several different clinical subtypes that warrant a comprehensive clinical assessment and subsequent targeted treatment and rehabilitation strategies. Recent advances in screening for vestibular and oculomotor impairment and symptoms (eg, Mucha and colleagues[17]) have revealed that many athletes experience these issues following SRC. Research also suggests that athletes with these issues often have longer recovery times and more pronounced impairment and symptoms following SRC.[25] In response to these findings, vestibular and vision therapists have begun to apply specific rehabilitation interventions to enhance the recovery process for those athletes with vestibular or oculomotor impairment and symptoms following SRC. Initial empirical evidence indicates that these vestibular and oculomotor interventions may be useful in mitigating these issues and enhancing the recovery of athletes with SRC. However, additional research regarding which interventions are most effective for each type of impairment and symptoms as well as the optimal number and length of therapeutic sessions needed to obtain the desired effect is warranted.

Most clinicians use some sort of OTC or prescription pharmacologic intervention to help manage lingering symptoms and impairment following SRC.[84] It is clear from clinical experience that when pharmacologic treatments are matched appropriately with patients' clinical subtypes and symptoms, they can be an effective intervention. However, there is some overlap for the effectiveness of certain pharmacologic interventions across more than one clinical subtype. Most pharmacologic treatments are implemented in patients with lingering (10–14 + days) or chronic (3 + months) symptoms and impairments. It is atypical for a patient to be prescribed a medication in the acute and subacute phases following a concussion. This "wait-and-see" approach may result in missed opportunities for effective early pharmacologic intervention following SRC. However, researchers have yet to determine how soon after injury the preceding pharmacologic treatments should be implemented to have the greatest therapeutic effect. In fact, it has been suggested that clinicians could accelerate recovery for some patients if pharmacologic treatments were implemented earlier in the injury process. In addition, researchers need to explore the effectiveness of various dosage levels, treatment regimens, and administration methods in patients following concussion.

This review was conceived to evaluate the evidence supporting current and emerging rehabilitation approaches for sport concussion. Consensus opinion for prescribed physical and cognitive rest is the most common rehabilitation approach for patients with concussion. However, more active and targeted rehabilitation strategies including vestibular and oculomotor rehabilitation and pharmacologic interventions have emerging evidence supporting their use. Ultimately, there is limited empirical support for the rehabilitation strategies discussed in this article, necessitating additional research on their effectiveness following concussion. This research should use multisite, RCT research designs to better elucidate the specific effects of individual interventions. In addition, future research should use comprehensive outcome assessments and targeted rehabilitation strategies that account for the heterogeneous nature of this injury.

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