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Review

Current concepts in sport concussion management: A multifaceted approach

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Abstract

Sport-related concussion is a common neurological injury that occurs in all levels of athletic participation. Concussions may actually go undiagnosed, as they do not always display outward signs and athletes may fail to report symptoms of concussion, either because they do not know the symptoms, or for fear of removal from play. Inappropriate management of concussion can lead to increased risk of subsequent injury. This article outlines various aspects of sport-related concussion management, including preparation/planning, education, evaluation, management, return to play decisions, and long term effects of concussion. Preparation and education are the first steps that must be taken to minimize the potentially negative consequences of concussion. If a concussion is suspected, it must be stressed that the evaluation should include a multifaceted approach, with a physical examination and assessment of signs and symptoms, neurocognition and balance. The management of concussion should include both physical and cognitive rest and factors such as transportation, sleep, work, and academics should be taken into consideration. Return to play following concussion should follow a graduated return to play protocol, with careful monitoring of symptoms. Sports medicine clinicians should stay up to date with information regarding concussion management and take a conservative approach, because there are recent reports of various cumulative effects of multiple concussions.

Keywords: Balance assessment; Cognitive rest; Mild traumatic brain injury (MTBI); Neurocognitive testing; Symptomatology

1. Introduction

Concussion, a form of mild traumatic brain injury (MTBI), is a common neurological injury that can occur in all levels of athletic participation. Concussion is a "complex pathophysiological process" which affects the brain and is caused by "traumatic biomechanical forces", such as a "direct blow to the head, neck, face or elsewhere on the body", in which the forces are transmitted to the head.[1] Sudden acceleration or deceleration of the head causes compressive, shear and/or tensile stress to cerebral tissue, typically resulting in a temporary decrease in neurological function and the development of post-concussive symptoms, sometimes including a loss of consciousness. However, it is estimated that less than 10% of sport-related concussions at both the high school and collegiate level result in a loss of consciousness.[2] While concussions may cause short-lived neurological changes or temporary disturbance of cerebral tissues, the acute symptoms of concussions are really the result of a functional injury, not a structural injury. It is important that concussions are properly diagnosed and managed in order to minimize potential negative effects due to the increased vulnerability to subsequent injury.[3]

Sports medicine clinicians should take on the role of educating athletes, coaches, and parents about concussions, especially since concussions may be under-reported.[4] Athletes may fail to report a concussion because they may not think that the injury is serious enough, they may not know that they

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suffered a concussion, or they may not want to be removed from play.[4] One study examining a sample of collegiate athletes found that 56% of athletes reported no knowledge of concussion consequences and 30.4% reported continuing to play with a headache after getting hit in the head.[5] If athletes understand concussions, they may receive faster and better care, because they are likely to report more details about their injury. For example, factors such as age, previous history of concussion and certain medical conditions (such as learning disabilities, history of migraines, and depression) can both predispose an individual to concussion and possibly delay recovery.[1] The better the knowledge of the clinician regarding athletes' history and concussion risk factors, the easier it will be for them to properly identify and manage concussions.

2. Epidemiology

It is estimated that over three million traumatic brain injuries occur in sports and recreational activities each year in the United States.[6] A number of these injuries are concussions. In fact, concussions account for about 9% of all high school athletic injuries and about 6% of all collegiate athletic injuries.[7] The rates of concussion have actually increased over the past decade; however, this could reflect the increased awareness of concussion due to education of the general public, or because of differences in data collection methods.[7–9] At the high school level, the concussion rate has been found to be between 2.3 and 2.5 concussions per 10,000 athlete-exposures, defined as one athlete participating in one athletic practice or competition.[9] Football accounts for the highest rate of concussion, followed by boy's ice hockey and boy's lacrosse.[7–9] Concussions are more likely to occur in games or competitions than practices and the most common mechanism of injury was contact with another person.[7–9] At the collegiate level, the concussion rate is estimated to be around 4.3 concussions per 10,000 athlete-exposures.[7–9] Once again football accounts for the highest concussion rates. The concussion rate for collegiate football is estimated to be between 4.9 and 6.9 concussions per 10,000 athlete-exposures.[2] At both the collegiate and high school level, females are more likely than males to sustain a concussion in sports in which the rules are similar between males and females.[7–10] It is hypothesized that these gender differences may be due to differences in cervical spine kinematics and neuromuscular control.[11] Studying the epidemiology of concussion is extremely important, because it helps determine injury rates and risk factors, which can ultimately provide implications for the prevention of future injuries.

3. Pathophysiology

Sport-related concussion is often the result of a direct blow to the head by another participant or object, but it can also be caused by an indirect force. Brain injuries that occur in sport can be classified as either focal or diffuse. Focal brain injuries usually result from a direct blow that causes damage to cerebral substances and vessels. Focal brain injuries result in more severe brain injuries, including macroscopic lesions (such as cortical or subcortical brain contusions) and intracerebral hematomas.[12] Concussions are diffuse brain injuries, and they vary in intensity from mild to severe. Diffuse injuries are caused by a linear impact, rotational/angular impact or a combination of linear and rotational impacts. They are often the result of sudden acceleration or deceleration of the head, which can cause compressive shear and tensile stress to cerebral tissue. Furthermore, diffuse injuries often result in shearing of white matter within the cortex to the midbrain and brainstem, and are not typically visible in diagnostic images.[12]

The mechanical trauma associated with concussion causes cell membranes and axons to be stretched, leading to a neurometabolic cascade.[13] Extracellular potassium concentrations rise because neurotransmitters, such as glutamate, release receptors that open ionic channels immediately after brain injury.[3,12] The opening of ionic channels leads to the accumulation of intracellular calcium, which in more severe cases can ultimately lead to apoptosis.[14] In addition, the sodium-potassium pump requires more adenosine-triphosphate (ATP) than usual, causing an increase in the glucose metabolism. The lack of glucose availability is the most likely explanation for the brain's vulnerability to subsequent injury immediately following a previous head injury.[3] The decreased glucose levels lead to mitochondrial dysfunction, ultimately resulting in the use of glycolytic pathways for energy. Lactate accumulates as a byproduct of aerobic metabolism, leading to acidosis, which has been shown to lead to ion disequilibrium and cerebral edema. Furthermore, evidence shows that cerebral blood flow decreases immediately following injury and will remain decreased for a time dependent upon the severity of injury.[15] These physiologic changes present themselves clinically as post-concussive signs and symptoms, deficits in postural stability and neuropsychological deficits.

4. Proper planning

Proper emergency planning is necessary for managing catastrophic brain injuries. Clinicians responsible for on-field care should begin planning before an injury even occurs. Health care providers should become familiar with the personnel who will be present for events, the emergency equipment that will be available and the communication system to be used to summon emergency care.[16] All personnel involved in event coverage should practice responding to emergency situations at least annually.[17] In addition, if a clinician works with a specific athlete or team, they should conduct pre-season screenings to gain information about their athletes, so they can better identify and manage injuries. Factors that have been associated with increased likelihood of sustaining a concussion, or prolonged recovery following concussion should be included in the pre-season screening questionnaires. Therefore, the questionnaire should include information about the number and severity of previous concussions and other head, face or cervical spine injuries, age, sport, medications, and premorbid conditions (such as learning disabilities, psychiatric disorders, or migraines).[1] It is also

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recommended that baseline symptom, neurocognitive and balance assessments are conducted, so that accurate comparisons can be made post injury. Furthermore, clinicians should create concussion policies that include preseason planning, the components of on-field or sideline evaluations, determinants of removal from play and a graduated return to play progression.[18] Proper planning is an essential component to proper evaluation, diagnosis, and management of concussion.

5. Education and prevention

One way to limit the negative consequences of concussion is through education. Sports medicine clinicians should educate athletes, coaches, parents, colleagues, and the general public about concussions. When putting together a concussion policy, healthcare providers should include an education component, outlining the responsibility of all athletes and personnel involved to report any symptoms of concussion to the sports medicine staff.[18] Education of athletes to improve awareness of the signs of concussion and potential risks of unreported concussions could prevent increased risk of cumulative or catastrophic effects following injury.[4] Furthermore, the promotion of fair play and strict enforcement of rules should be encouraged in all sporting associations. Coaches, officials, and parents play an important role in ensuring that rules are properly enforced. In addition, there is some evidence that instruction of proper skill to heighten awareness during sporting events may have implications for concussion prevention. Coaches should instruct athletes on the proper biomechanics for the skills required for their sport, focusing on being in a position of "athletic readiness" and keeping their head up, which should allow for anticipation of impending collisions. One study found that anticipation of impending collisions decreased the severity of head impacts in youth ice hockey.[19] Furthermore, it is possible that neck musculature strengthening could help reduce impact forces transmitted to the brain, by dissipating forces over a greater area,[11] but there is little scientific evidence to support this theory.

Recent discussion has centered around the role of protective equipment in the prevention of concussions.[20] While most protective equipment has been found to prevent some type of head injury (such as skull fractures or dental injury), there is little evidence to support the use of any protective equipment to reduce the risk and/or severity of concussions. For example, while there is strong evidence to support the use of mouthguards to reduce the incidence of dental injuries, there is not strong evidence to support the use of mouthguards to prevent concussions or reduce the severity of concussions.[21,22] In addition, while helmets have been found to reduce the risk of head injuries, especially in bicycling, skiing and snowboarding, there is not strong evidence to support that helmets reduce the risk and/or severity of concussions. There is some evidence that newer models of football helmets may reduce translational and rotational accelerations, which may help reduce diffuse axonal injury.[20] However, the true role of reduced translational and rotational accelerations in concussion prevention is unclear.[20] Another theory is that the increased size and padding of recent helmets provide increased attenuation of impact forces associated with concussions than helmets from the 1970's through 1990's.[23] While there is not conclusive evidence to support the use of protective equipment to prevent concussions, there is evidence to support its use to reduce a number of other types of injuries and should therefore be worn to all practices and games. Furthermore, protective equipment should be up to date and fitted properly, and it should not be used as a weapon.

6. Evaluation

6.1. On-field/Initial clinical evaluation

The on-field or initial assessment of concussion is a crucial part of the evaluation process. The identification of concussions can be very challenging, since some athletes may not report their symptoms and there are not always visible signs of concussion. If an athlete is unconscious, a cervical spine injury should always be suspected. Upon arrival on the field/court, the clinician should perform a primary survey, including assessment of the athlete's airway, breathing, and circulation. If the athlete remains unconscious, emergency medical services should be summoned and appropriate emergency care should be provided. If the athlete regains consciousness, cervical spine injuries, cranial fractures and other serious or potentially life-threatening conditions should be ruled out before removing the athlete from the field. Even if an athlete regains consciousness following a concussion, or never loses consciousness from a concussion, he or she should be sent or taken to the emergency department if they present with any "red flags".[24] "Red flags" include headaches that worsen, looking very drowsy or cannot be awakened, inability to recognize people or places, unusual behavior changes, seizures, repeated vomiting, increased confusion, increased irritability, neck pain, slurred speech, and weakness or numbness in arms or legs.[24]

Once all serious and life-threatening conditions are potentially ruled out and the athlete is stable, the sideline clinical evaluation can begin. The sideline evaluation should at least include history, observation, palpation, and special tests. The history should be thorough and initially should be used to confirm the level of consciousness and presence or absence of amnesia. The presence or absence of amnesia can be established by questioning the athlete about events that occurred before the injury (retrograde amnesia) and events that occurred following the injury (anterograde amnesia). The history should also include questions about the mechanism of injury, location of impact, if loss of consciousness was experienced, and if so for how long, and the presence and length of post-concussive seizures.[25] If not already completed, the observation and palpation of the athlete should include the observation of pupil size (for equivalency), pupils' reaction to light and the presence or absence of nystagmus (involuntary eye movement). In addition, vital signs, such as pulse and blood pressure should be taken in order to further rule out life-threatening conditions.

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Furthermore, the cervical spine, skull and facial bones should be palpated to rule out fractures. Range of motion and strength tests can also be used to determine the extent of cervical spine injury, if indicated, but should not be used if there is a suspected fracture. Finally, the sideline evaluation should include a symptom checklist, a mental status assessment and a balance assessment. It is crucial to obtain sideline measures of symptoms, mental status and balance in order to track recovery over time.

There are a number of tools that can be used to assess symptoms, mental status and balance on the sideline, following a suspected concussion. Symptom assessment should utilize a symptom checklist, which includes a grading scale for the severity of each of the symptoms. An example of an appropriate symptom checklist is the Graded Symptom Checklist, which has 22 symptoms that the athlete grades on a severity scale of 0−6 (Appendix 1). If an athlete presents with any signs or symptoms of a concussion following a mechanism of injury consistent with concussion, such as a blow to the head, he or she should be suspected to have a concussion and should be withheld from physical activity at least for the remainder of the day.[1] A commonly used mental status examination is the Standardized Assessment of Concussion (SAC), which is a paper and pencil exam that only takes about 5 min to administer. The SAC includes sections assessing orientation, immediate recall, concentration, and delayed recall and has been shown to be both valid and reliable in college athletes.[26−28] A commonly used balance assessment is the Balance Error Scoring System (BESS), which involves a series of stances that are completed on both a firm and foam surface. While it is believed that some practice effects may exist on the BESS, the overall reliability has been found to be between 0.60 [29] and 0.92,[30] and the BESS has been shown to be valid.[31] All of these evaluation tools should be used on the sideline following injury and can be repeated over time to track recovery.

Serial monitoring for deterioration following concussion, especially over the first few hours following injury, is essential in the proper management of concussion. Athletes and a designated "care taker" should be educated about the "red flags" to watch for over the first 24−48 h following concussion. As long as the individual is not displaying signs of an intra-cerebral lesion, such as prolonged disturbance of conscious state or prolonged symptoms, focal neurological deficit or worsening symptoms, neuroimaging is typically not necessary. Conventional structural neuroimaging is thought to be normal in concussed individuals.[1] The athlete should be educated about physical and cognitive rest and should not be allowed to return to activity on the same day.[1] Once asymptomatic, the athlete should be re-assessed to determine whether it is appropriate to begin a return to play protocol.

6.2. Signs and symptoms

Signs and symptoms of concussion range from obvious signs, such as altered levels of consciousness, to milder self-reported symptoms, such as a headache. The signs and symptoms of concussion can be stratified into a number of clinical domains, including somatic symptoms (i.e., headache, nausea), neurobehavioral symptoms (i.e., sadness or depression), or cognitive symptoms (i.e., feeling "in a fog", difficulty concentrating, difficulty remembering).[25] Individuals with a concussion may report signs and symptoms within any of the clinical domains or within a combination of the clinical domains. Signs and symptoms play a vital role in the evaluation of concussion and return to play decisions.[1] Therefore, symptom inventory should be used initially following injury and over time to track recovery. Typically, a symptom checklist that allows the athlete to denote not only the number of symptoms, but the severity of symptoms (typically utilizing some type of Likert scale) is used. The responses are then summed to obtain a total symptom score, which can be used as a measure of the severity of the concussion and help track recovery.

Certain concussion symptoms appear to be more common than others. The most frequently reported symptoms post-concussion include headaches, fatigue, feeling "slowed down", drowsiness, difficulty concentrating, feeling "mentally foggy" and dizziness.[32] The least frequently reported symptoms post-concussion include nervousness, feeling more emotional, sadness, numbness or tingling and vomiting.[32] Certain symptoms have also been linked to prolonged recovery. In high school football athletes, dizziness at the time of injury was associated with prolonged recovery time.[33] Additionally, self-reported cognitive decline and migraine headache symptoms were found to be associated with increased recovery time in high school football athletes.[34] Therefore, if an individual is exhibiting symptoms that are associated with a prolonged recovery, their clinician may consider using a more conservative management approach.

6.3. Neurocognitive assessment

Tests of mental status evaluate the immediate neurocognitive effects of concussion, such as alterations in short-term or working memory. Several methods exist for evaluating the mental status and cognitive function of a concussed athlete. While the SAC is useful for initially detecting a concussion and tracking recovery during the early stages following injury, most college athletes will return to baseline performance on the SAC within 48 h following injury.[26] Therefore, after the sideline evaluation, more sophisticated neurocognitive tests may be used. Traditionally, paper and pencil neurocognitive tests have been used, but recently computerized concussion assessment tests have become available.[35] Some advantages of computerized neurocognitive tests include ease of administration, shorter time period needed for testing, and presence of multiple forms of tests, in order to minimize practice effects.[35] There are several different types of computerized neurocognitive test batteries used by clinicians to assess concussions, including the Immediate Post-Concussion Assessment and Cognitive Testing, Automated Neuropsychological Assessments

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Matrix, CogSport, Concussion Resolution Index and Concussion Vital Signs. Typically computerized concussion assessments include a symptom checklist utilizing a Likert scale, a verbal and visual memory component, and various measures of attention, concentration and reaction time. The cognitive tests included in the computerized assessments have been validated against traditional neurocognitive tests, such as the Hopkins Verbal Learning Test-Revised, the Brief Visuospatial Memory Test-Revised and the Symbol Search and Digit Symbol-Coding subtests of the Wechsler Adult Intelligence Scale-Third Edition.[36,37] It is suggested that baseline measures of neurocognitive performance are collected to control for individual pre-injury levels of neurocognition. Due to the variability amongst athletes, if baseline assessments are available, post-injury scores should be compared to baseline scores. If baseline scores are not available, and the individual does not have any premorbid neurocognitive or psychiatric conditions, recent data suggests that post-injury scores may be carefully compared to normative data in the college population.[38,39]

The assessment of neurocognition is important because neurocognitive deficits have been found following concussion, even after all other signs and symptoms have resolved.[40] Decreased performance on a computerized measure of reaction time in concussed high school football athletes was found to be associated with increased recovery time.[34] Also, younger concussed athletes were found to take longer to recover on verbal memory, visual memory and reaction time than older concussed athletes.[41] While neurocognitive assessment is a vital piece of the evaluation of concussion, it should not be the sole basis of management and return to play decisions. Neurocognitive testing should be used in addition to sideline clinical measures, symptom assessments and balance assessments to guide the evaluation and management of concussion.

6.4. Balance assessment

Deficits in postural stability have also been noted following concussion.[42] Several methods for evaluating postural stability following concussion exist. Initially, simple examinations such as Rhomberg and stork stand test were commonly used for evaluating postural stability following concussion. Currently, common methods include the BESS and the use of force plates. The BESS is an objective assessment tool developed to assess postural stability following concussion. It is portable, cost-effective and can be used in the absence of a more expensive or sophisticated tool.[29,43] The BESS involves three different stances (double leg, single leg, and tandem stance), which are completed twice (once on a firm surface and once on an unstable surface), for a total of six 20-s trials.[29,43] The BESS is scored by recording the number of errors for each trial. Errors include lifting hands off iliac crests, opening eyes, stepping, stumbling or falling, moving the hip into greater than 30 degrees of flexion or abduction, forefoot or heel losing contact with the ground or remaining out of the testing position for more than 5 s.[44]

6.5. Multifaceted approach

It is extremely important that the evaluation and management of concussion takes a multifaceted approach to include a clinical evaluation, symptom checklist, neurocognitive assessment, and balance assessment. More contemporary management protocols have de-emphasized the use of grading of concussion, since valid concussion evaluation tools are readily available and allow the clinician to objectively assess the signs and symptoms of concussion. In addition, the variability surrounding concussion recovery indicates that each case should be managed individually based upon the information and circumstances specific to that case.

7. Management

Concussion management should be based on both physical and cognitive rest, because returning to physical or cognitive activities too soon may exacerbate symptoms and delay the recovery process.[45] If an athlete is suspected of having a concussion, he or she should be immediately removed from play, and should continue with complete physical rest (including removal from activities such as sports practices, biking and jogging) until his/her symptoms resolve and he/she is re-evaluated. Cognitive rest should involve limiting activities that require attention and concentration, such as school work or using the computer. Symptoms should be monitored on at least a daily basis and any activities that are associated with an increase in symptoms should be limited as much as possible. While it may be hard to limit school work or office work, sports medicine clinicians should work with schools and employers to make accommodations for injured students and employees. If complete cognitive rest is not manageable, the patient should at least limit their time in class, or working on a computer, and be sure to take frequent breaks throughout the day. While cognitive rest is considered to be an important aspect of recovery, there is little evidence to support the benefit of cognitive rest. Future research should examine the effects of cognitive rest on recovery following concussion.

In addition, there are several factors that can complicate the management of concussion. These “modifiers” were presented by the International Sport Concussion Consensus Statement — Zurich Guidelines,[1] included in Table 1. These “modifying” factors may influence the management of concussion, and in some cases may predict the potential for prolonged recovery. Special considerations should be taken if individuals have these “modifying” factors and it may be wise to be more conservative when making return to play decisions with these athletes.

7.1. Considerations for cognitive rest

Returning to full cognitive activities too soon can be frustrating to the athlete and can prolong recovery. If an athlete returns to too much cognitive activity, too soon, it is hypothesized that this provides further stress to the brain, which is already in a vulnerable state, ultimately leading to an increase

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Table 1
Modifiers of concussion (adapted from the Zurich Guidelines— 2009[1] with permission).

Factor	Modifier
Symptoms	Number, duration (>10 days), severity
Signs	Prolonged loss of consciousness (>1 min), amnesia
Sequelae	Concussive convulsions
Temporal	Frequency (i.e., repeated concussions over time), Timing (i.e., injuries close together in time)
Threshold	Repeated concussions occurring with progressively less force, or slower recovery with each subsequent concussion
Age	Children and adolescent populations (<18 years old)
Comorbidity and premorbidity	Migraines, depression, attention deficit hyperactivity disorder (ADHD), learning disorders, sleep disorders, mental health disorders
Medication	Psychoactive drugs and anticoagulants
Behavior	Dangerous style of play, improper biomechanics
Sport	High-risk activity, high level of sport, contact and collision sports

in post-concussive signs and symptoms.[46] In addition, concussions can directly affect learning, because the concussion symptoms, such as headache, blurred vision, drowsiness, sensitivity to light, sensitivity to noise, "feeling in a fog", difficulty concentrating, difficulty remembering, and ringing in the ears, may make learning difficult. Furthermore, if a concussed athlete has a modifier of concussion, such as learning disability, where they already have difficulty paying attention in class, the return to full cognitive activities could be extremely challenging. Therefore, student-athletes, especially those with certain modifiers may need to take a break from school altogether, initially following injury. It is important to educate school officials regarding concussion in order to allow athletes proper cognitive rest following concussion. If possible, a concussion policy should be put in place, in order to allow students proper recovery time. Athletes who sustain a concussion may also benefit from other forms of cognitive rest, including limitation of computer use, watching television, playing video games, and talking or text messaging on a cell phone.

An often times overlooked portion of cognitive rest is the operation of motor vehicles. Driving a car requires concentration, adequate reaction time and alertness. All of these factors are potentially affected following concussion. As previously discussed, concussion symptoms can cause difficulty concentrating and drowsiness. In addition, reaction time is often decreased post-injury. Therefore, considerations regarding driving vehicles post-concussion should take symptoms and cognitive measures into account, as returning to driving too soon following injury can prolong recovery, and can be very dangerous to the driver and other individuals on the road.

Not all individuals and not all concussions are the same, so an individualized approach should be taken in the limitations placed on cognitive activities. The level of cognitive activity that is tolerable and does not worsen or recreate symptoms is unique for every individual and will change throughout the course of recovery.[46] Initially following injury, most athletes may need to significantly limit their cognitive activities. However, usually as the athlete begins to recover, some cognitive activity is actually beneficial to healing. A retrospective study examining the influence of post-concussion activity levels on symptoms and neurocognitive performance in student-athletes found that patients who participated in a moderate level of activity had the best outcome.[45] Therefore, there should be a careful balance between cognitive rest and cognitive activity during the recovery process. The acceptable amount of cognitive activity should be determined by continuously monitoring symptoms and determining the level of cognitive activity that does not cause the worsening or reappearance of symptoms.

7.2. Considerations for physical rest

Physical rest following sports-related concussion begins with immediate removal of the athlete from play. Removal from play is designed to protect the athlete from a second blow to the head, which could prolong recovery or even lead to catastrophic injury. In addition, physical exertion could lead to an increase, or worsening of symptoms, especially in the early stages of recovery. While it is widely accepted that athletes should be removed from activity following concussion, often times other forms of physical rest, such as participation in gym or fitness classes, recreational play, or bicycling to school/work are forgotten. Any form of physical activity that causes an increase or reproduction of symptoms should be avoided.

Sleep is another form of physical rest that is not always addressed following concussion. Complaints of sleep disturbances are often reported following concussion, and are problematic, because sleep deprivation has been shown to cause cognitive impairments.[47] Sleep disturbances often lead to continuous wakefulness, resulting in changes to the brain, such as decreased metabolic resources or oxidative damage to neurons. These metabolic changes within the brain are responsible for the cognitive impairments. Additionally, these metabolic impairments in a brain that already lacks energy because of concussion, could potentially delay recovery. Therefore, athletes recovering from concussion should be encouraged to establish a sleep schedule and get an adequate amount of sleep each night. If the athlete is reporting sleep disturbances, they should be encouraged to eliminate any distractions from their bedroom so that they are sleeping in a quiet, dark room. They should also be encouraged to avoid the use of caffeine, nicotine and alcohol.[48] If an athlete's sleep disturbances cannot be managed utilizing conservative management, medications should be considered.

8. Return to play

8.1. Making return to play decisions

The return to play decision following concussion is a very important decision that should occur gradually and not all in one step. Each concussion puts an individual at an increased

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risk for sustaining another concussion, so return to play decisions should be made using a multitude of information, in order to increase the accuracy of the decision.[49] A variety of concussion assessment tools, including a symptom checklist, neurocognitive measures and balance measures, exist for the use in evaluation, management, and ultimately return to play decisions. It must be stressed that one single component, such as neurocognitive testing, should not be used solely to make decisions, but instead a multi-faceted approach should be used. Return to play should not be considered until an athlete is completely asymptomatic. In addition, the athlete should have returned to baseline or normative values on neurocognitive and balance assessments. Athletes should be administered a symptom checklist prior to beginning the return to play protocol and should be monitored for any return of signs and symptoms throughout the protocol. A sample return to play protocol is included in Table 2.

The return to play progression may begin once the athlete is asymptomatic and has returned to baseline on follow-up assessments. If the exertional activities performed at each level of the progression do not produce acute symptoms, they may progress to the next step. Generally each step should take 24 h, which allows for monitoring of both acute (during the activity) symptoms and delayed (within 24 h after the activity) symptoms.[1] The athlete should be monitored periodically throughout and after these sessions using objective assessment measures to determine if an increase in intensity is warranted. If at any point during the return to play progression the athlete's symptoms return, a minimum of 24 h without symptoms should be required before reintroducing the protocol, beginning at Step 1. This general gradual return to play protocol allows for an individualized approach, that permits concussions to be managed based on the presentation of the injury and the activity to which the athlete is trying to resume.

8.2. When to disqualify an athlete

The decision to medically disqualify an athlete from participation following concussion is always a difficult and challenging decision to make, which involves a very complex evaluation process. There are not any specific predictors of long-term recovery following concussion. While loss of consciousness and/or amnesia have not been linked to prolonged recovery or long-term consequences, these cases should be carefully monitored and return to play decisions should be more conservative. The decision to disqualify an athlete from activity should be based on a thorough, comprehensive physical examination and serial assessment of symptoms, neurocognitive functioning and balance. In addition, the athlete's previous history of concussions, amount of time between concussions, amount of force required to cause subsequent concussions and length of recovery for subsequent concussions should be taken into consideration. If an athlete has a history of multiple concussions, which are requiring progressively less force to cause injury and are requiring progressively longer recovery times following each concussion, temporary or permanent disqualification from contact sports should be considered.

Table 2
Graduated return to play protocol (Adapted from Zurich Guidelines— 2009[1] with permission).

Rehabilitation stage	Functional exercises
1 – No activity	Complete physical and cognitive rest
2 – Light aerobic activity	Walking, swimming, stationary biking (<70% MHR)
3 – Sport specific exercise	Running drills, *etc.*
4 – Non-contact training drills	Passing drills, can begin resistive exercise
5 – Full contact practice	Following medical clearance, full practice
6 – Return to play	Return to full participation, including games/competitions

9. Long-term effects

The potential for long-term effects of repetitive MTBIs has recently been recognized.[50] While in most cases, concussions fully resolve within weeks of the injury, there is recent evidence to suggest that concussions can have cumulative and long-term effects. Retired professional football players who reported three or more concussions had a 5-fold prevalence of mild cognitive impairment and a 3-fold prevalence of reporting significant memory problems, when compared to retired professional football players with no history of concussion.[51] In addition, there was an earlier onset of probable Alzheimer's Disease in the retired professional football athletes than there is in the general United States male population.[51] A similar study found a link between recurrent concussion and clinical depression in retired professional football players.[52] These findings suggest that certain features of dementia-related syndromes and depression may be associated with repetitive cerebral concussion.[51] Similarly, repetitive brain trauma has been linked to a "progressive neurological deterioration", known as chronic traumatic encephalopathy (CTE).[53] CTE is associated with memory problems, changes in personality and impaired speech and gait.[53] It is possible that the long-term effects of concussion could be prevented by decreasing the frequency and severity of sport related concussion. This will likely require a sport specific approach that concentrates on limiting exposure of high-risk athletes, biomechanical modifications, rule changes, and increased education or awareness.

10. Conclusion

Sport-related concussion is an injury that most sports medicine clinicians will manage at some point in their career. A recent increase in literature and media surrounding sport-related concussion has allowed for better education. Nonetheless, sports medicine clinicians should play an active role in educating athletes, coaches, parents, and other relevant personnel about concussions. This is perhaps the most important component of concussion prevention and initial recognition. Sports medicine clinicians should also take an active role in prevention of concussion with emergency planning, concussion management

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plans, and implementation of pre-participation examinations. If clinicians work for high-risk athletes and/or teams and sufficient resources are available, they should also consider conducting baseline measures of symptoms, neurocognition, and postural stability, so that accurate individual comparisons can be made post-injury. Initial evaluation of concussion should involve ruling out life-threatening and serious conditions and completing initial concussion assessment tests, such as the SAC, BESS and a symptom checklist. Management of concussion should include both physical and cognitive rest and should take factors such as sleep, transportation, work, and academics into consideration. Over the past decade, there has been an evolution of concussion assessment tools, which allows clinicians to gain more objective measurements with regards to signs, symptoms, neurocognition, and postural stability, allowing for better management and return to play decisions. Once an athlete is recovered and ready to be returned to activity, clinicians should guide them through a gradual return to play protocol, with careful monitoring of symptoms throughout the process. Health care providers should take a conservative approach to concussion management, especially since there are recent reports of various cumulative effects of multiple concussions. Overall, clinicians should make sure that they are staying up to date with their knowledge of concussion prevention, evaluation, management, and return to play decisions, and make sure to educate their athletes, coaches and parents about the prevention, reporting and long-term consequences of concussion.

Appendix 1. Graded symptom checklist.

Concussion graded symptom checklist (GSC)
Grade symptoms 0−6

Instructions: The GSC should be used not only for the initial evaluation, but for each subsequent follow-up assessment until all signs and symptoms have cleared at rest and during physical exertion. In lieu of simply checking each symptom present, the athlete should be asked to grade or score the severity of the symptom from 0 to 6, where 0 = not present, 1 = mild, 3 = moderate and 6 = most severe.

Symptom	Date	Date	Date	Date	Date	Date
Blurred vision						
Dizziness						
Drowsiness						
Excess sleep						
Fatigue						
Feel "in a fog"						
Feel "slowed down"						
Headache						
Inappropriate emotions						
Irritability						
Memory problems						
Nausea						
Nervousness						
Poor balance/coordination						
Poor concentration						
Ringing in ears						
Sadness						
Sensitivity to light						
Sensitivity to noise						
Sleep disturbance						

Daily physical and cognitive activities:

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