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Mark E. Halstead, Kevin D. Walter and The Council on Sports Medicine and Fitness

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Clinical Report—Sport-Related Concussion in Children and Adolescents

Mark E. Halstead, MD, Kevin D. Walter, MD, and THE COUNCIL ON SPORTS MEDICINE AND FITNESS

KEY WORDS
concussion, sports, head injury, mild traumatic brain injury, return to play, athletes, second-impact syndrome, postconcussion syndrome

ABBREVIATIONS
CIS—concussion in sport
LOC—loss of consciousness
SAC—Standardized Assessment of Concussion
BESS—Balance Error Scoring System
SCAT2—Sport Concussion Assessment Tool 2
CT—computed tomography

The guidance in this report does not indicate an exclusive course of treatment or serve as a standard of medical care. Variations, taking into account individual circumstances, may be appropriate.

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abstract

FREE

Sport-related concussion is a "hot topic" in the media and in medicine. It is a common injury that is likely underreported by pediatric and adolescent athletes. Football has the highest incidence of concussion, but girls have higher concussion rates than boys do in similar sports. A clear understanding of the definition, signs, and symptoms of concussion is necessary to recognize it and rule out more severe intracranial injury. Concussion can cause symptoms that interfere with school, social and family relationships, and participation in sports. Recognition and education are paramount, because although proper equipment, sport technique, and adherence to rules of the sport may decrease the incidence or severity of concussions, nothing has been shown to prevent them. Appropriate management is essential for reducing the risk of long-term symptoms and complications. Cognitive and physical rest is the mainstay of management after diagnosis, and neuropsychological testing is a helpful tool in the management of concussion. Return to sport should be accomplished by using a progressive exercise program while evaluating for any return of signs or symptoms. This report serves as a basis for understanding the diagnosis and management of concussion in children and adolescent athletes. *Pediatrics* 2010;126:597–615

INTRODUCTION

Since 1999, an extensive amount of research and media coverage has been dedicated to sport-related concussions. Young athletes pose a unique challenge, because their brains are still developing and may be more susceptible to the effects of a concussion. Even 10 years ago, a young athlete with a "ding" or low-grade concussion would have been allowed to return to sports as soon as 15 minutes after his or her symptoms had cleared. Since then, more extensive research has provided medical professionals with a better understanding of the symptomatic course and risk of potential long-term complications from concussions. As a result, management has evolved. Unfortunately, many parents, coaches, and young athletes still seem to believe that youth is a period of indestructibility. Concussion education in youth and high school sports communities is complicated by the misconception that a concussion may be "toughed out" and does not require a physician visit. Research and carefully documented experience show otherwise, although to the people who believe those misconceptions, it may seem as though the landscape of managing concussion has changed overnight.

Some organizations, such as the American College of Sports Medicine and National Athletic Trainers Association, have addressed sport-related concussions in position statements.[1,2] Three international symposia on concussion in sport (CIS) have been held since 2001, although none focused exclusively on the pediatric athlete.[3–5] Although the Canadian Paediatric Society published guidelines on the management of the pediatric concussion, new research has been conducted since that statement.[6] This report outlines the current state of knowledge on pediatric and adolescent sport-related concussions.

DEFINITION

A clear definition of concussion requires consensus among researchers, clinicians, and patients, each of whom require a different construct for understanding the injury. Some advocate using the term "concussion," and others advocate using the term "mild traumatic brain injury" (mTBI). A recent study highlighted a general misinterpretation that an injury described as a concussion is less severe than one described as mild traumatic brain injury, which may result in a premature return to school and activity.[7] In this clinical report, we will refer to the injury as concussion.

The first of 3 international symposia on CIS was held in Vienna, Austria, in 2001.[3] From that meeting came a new consensus definition for a sport-related concussion, with minor revisions occurring in the 2 subsequent symposia held in Prague, Czech Republic, in 2004[4] and Zurich, Switzerland, in 2008.[5] The Zurich statement defined concussion as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces"[5] and includes 5 major features:

1. Concussion may be caused either by a direct blow to the head, face, or neck or elsewhere on the body with an "impulsive" force transmitted to the head.
2. Concussion typically results in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously.
3. Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury.
4. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness (LOC). Resolution of the clinical and cognitive symptoms typically follows a sequential course; however, it is important to note that in a small percentage of cases, postconcussive symptoms may be prolonged.
5. No abnormality on standard structural neuroimaging studies is seen in concussion.

Biokinetics and Pathophysiology

The biokinetics that induce a concussion consist primarily of acceleration-deceleration and rotational forces.[8,9] It has been proposed that greater force is required to produce an injury to the pediatric brain than to the adult brain.[10] Adults typically develop more intracranial injury in association with skull fractures than do children.[11] These findings may be related to the developing brain and skull, but it is unclear whether this model applies to sport-related concussion.

The pathophysiology of a concussion, as described from animal models, starts with a disruption of the neuronal membrane, which results in a potassium efflux to the extracellular space with a subsequent release of glutamate, an excitatory amino acid.[12] Glutamate potentiates further potassium efflux, which results in the depolarization and suppression of neuronal activity. To restore ion balance, the sodium-potassium ion pumps increase activity, which results in excessive adenosine triphosphate consumption and glucose utilization.[13] Lactate accumulates and cerebral blood flow decreases, which leads to a proposed "energy crisis."[13] A large amount of calcium also accumulates in cells, which may impair oxidative metabolism and allow for the initiation of biochemical pathways that result in cell death.[13] After the increase in glucose metabolism, there is a subsequent hypometabolic state that may persist for up to 4 weeks after injury.[14,15] Because the pathophysiology has only been established from animal models, it is still unclear whether this can be applied to the sport-related concussion.[16]

Grading Scales

There are more than 25 different published grading systems for concussions.[17] They were developed through expert opinion and rely heavily on LOC and a few symptoms, such as confusion and amnesia, to determine the severity of the concussion and subsequent return to play. The 3 concussion-grading scales most commonly used are the American Academy of Neurology,[18] Colorado Medical Society,[19] and Cantu[20,21] grading systems. In recent consensus statements, the CIS group recommended abandoning the use of grading scales and endorsed using several evaluation measures to individually guide return-to-play decisions.[3–5] In the 2004 Prague statement, the CIS group subsequently introduced the classification of concussions into simple and complex groups.[4] These groups were subsequently abandoned in the 2008 Zurich statement, because the delineation was also arbitrary and not found to be useful in managing concussion.[5] The current recommendation remains the abandonment of previous grading scales for a symptom-based approach for determination of return to play.[5]

EPIDEMIOLOGY OF CONCUSSION

It is commonly reported that 300 000 sport-related concussions occur each year, although it was estimated in a recent review that up to 3.8 million recreation- and sport-related concussions occur annually in the United States. The large variance is attributable to original estimates including concussions that only involved LOC.[22,23] This highlights the difficulty with concussion epidemiology because of underreporting and the lack of widespread use of an injury surveillance system in youth sports.[24,25] With increasing access to recreational and organized (club and school) sports, as well as better awareness and recognition of the injury, the number of diagnosed concussions will likely increase. Because of the large numbers of participants in youth and high school sports, concussions in the pediatric and adolescent age groups account for the majority of sports-related concussions.

Concussions represent an estimated 8.9% of all high school athletic injuries.[26] Data are significantly lacking about concussions in grade school and middle school athletes, which highlights the need for more research about concussions in this younger age group.

Girls are reported to have a higher rate of concussion than boys in similar sports.[26–30] The reason for this difference is unknown, although some have theorized that female athletes have weaker neck muscles and a smaller head mass than their male counterparts.[31,32] Alternatively, male athletes may be more reluctant to report their injuries for fear of removal from competition, which may result in the incidence of concussion in boys being underestimated.[24,33]

The sport with highest risk of concussion in high school is football (Table 1).[26] In girls' sports, the rate of concussion is highest in girls' soccer and girls' basketball. Rugby, ice hockey, and lacrosse also account for higher rates of concussions but are often club sports, which limits their data inclusion in the larger high school sports epidemiologic studies.[34–37]

TABLE 1 Concussion Rates in High School Sports

Sport	Injury Rate, per 1000 Athlete Exposures
Football	0.47–1.03[a,b]
Girls' soccer	0.36[a]
Boys' lacrosse	0.28–0.34[c,d]
Boys' soccer	0.22[a]
Girls' basketball	0.21[a]
Wrestling	0.18[a]
Girls' lacrosse	0.10–0.21[c,d]
Softball	0.07[a]
Boys' basketball	0.07[a]
Boys' and girls' volleyball	0.05[a]
Baseball	0.05[a]

[a] Data from Gessel LM, Fields SK, Collins CL, Dick RW, Comstock RD. Concussions among United States high school and collegiate athletes. *J Athl Train.* 2007;42(4):495–503.
[b] Data from Guskiewicz KM, Weaver NL, Padua DA, Garrett WE. Epidemiology of concussion in collegiate and high school football players. *Am J Sports Med.* 2000;28(5):643–650.
[c] Data from Lincoln AE, Hinton RY, Almquiest JL. Head, face, and eye injuries in scholastic and collegiate lacrosse: a 4-year prospective study. *Am J Sports Med.* 2007;35(2):207–215.
[d] Data from Hinton RY, Lincoln AE, Almquist JL. Epidemiology of lacrosse injuries in high school-aged girls and boys: a 3-year prospective study. *Am J Sports Med.* 2005;33(9):1305–1314.

SIGNS AND SYMPTOMS

The signs and symptoms of concussion fall into 4 categories: physical, cognitive, emotional, and sleep (Table 2).[38] Headache is the most frequently reported symptom.[39] LOC occurs in less than 10% of concussions but is an important sign that may herald the need for further imaging and intervention.[40–42] Along with LOC, amnesia may be an important indicator of more serious injury.[40] The athlete should be evaluated for retrograde (before the event) and anterograde (after the event) amnesia by asking questions about details of events before and after the injury. The symptoms of retrograde amnesia may improve over time.[43] Often, the athlete hears peers, family, and coaches discuss events surrounding the injury and, subsequently, may falsely report remembering more about the injury. Mental fogginess may be a good predictor of a slower recovery from concussion in athletes.[44]

The signs and symptoms of concussion are similar to depression, anxiety, and attention-deficit disorders. In patients with preexisting mental health disorders, concussion may exacerbate those symptoms and make them more difficult to control. It is important to monitor this population carefully and consider altering existing care plans. Patients with learning disabilities and cognitive delays will also exhibit similar signs and symptoms, which can increase the challenge of managing their concussion.

Several factors may complicate the recognition of concussion for the athlete. Athletes may not recognize that they have concussion symptoms because of poor understanding of a concussion and its associated symptoms or from cognitive impairment from the injury itself. Symptoms may not ap-

TABLE 2 Signs and Symptoms of a Concussion

Physical	Cognitive	Emotional	Sleep
Headache	Feeling mentally "foggy"	Irritability	Drowsiness
Nausea	Feeling slowed down	Sadness	Sleeping more than usual
Vomiting	Difficulty concentrating	More emotional	Sleeping less than usual
Balance problems	Difficulty remembering	Nervousness	Difficulty falling asleep
Visual problems	Forgetful of recent information		
Fatigue	Confused about recent events		
Sensitivity to light	Answers questions slowly		
Sensitivity to noise	Repeats questions		
Dazed			
Stunned			

pear until several hours after a concussive episode.[4] In addition, young athletes may not be forthcoming with their symptoms for fear of activity restrictions.

A number of immediate motor phenomena, such as tonic posturing or convulsive movements, may accompany a concussion.[5] These immediate responses are uncommon, are generally benign, and require nothing more than standard management of the underlying concussion.[5,45] Although a brief seizure immediately after a concussive impact may not be problematic, any athlete who has a seizure after concussion should be transported emergently to a medical facility for further evaluation.

An athlete may be followed through his or her recovery with the use of the postconcussion symptom scale (Table 3). Although there are several variations, a 22-item symptom list is most commonly used. The scale is a 7-point Likert scale graded from 0 (no symptoms) to 6 (severe symptoms). An athlete may be more likely to report symptoms if given a graded scale than if asked a "yes" or "no" question. These scales have validity but have not been assessed adequately for reliability.[46,47] Results of a recent analysis of various symptom scales suggest that a 13-item checklist may be more helpful, but further research is needed to validate that recommendation.[48] Symptom scales have not been adequately studied in the grade school athlete.[47] At any age, it is important to make sure the patient understands what each symptom means and is able to complete the symptom scale independent of parental influence. Athletes with preinjury depression, sleep disturbances, and/or attention-deficit/hyperactivity disorder may not be expected to have a total score of 0 on a symptom scale before considering return to play. The evaluator must take a thorough history of the patient and account for these problems when making decisions about return to play.

TABLE 3 Postconcussion Symptom Scale (no Symptoms, 0; Moderate, 3; Severe, 6)

Headache	0	1	2	3	4	5	6
Nausea	0	1	2	3	4	5	6
Vomiting	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Fatigue	0	1	2	3	4	5	6
Trouble falling to sleep	0	1	2	3	4	5	6
Excessive sleep	0	1	2	3	4	5	6
Loss of sleep	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Light sensitivity	0	1	2	3	4	5	6
Noise sensitivity	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervousness	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Numbness	0	1	2	3	4	5	6
Feeling "slow"	0	1	2	3	4	5	6
Feeling "foggy"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Visual problems	0	1	2	3	4	5	6

Use of the postconcussion symptom scale: The athlete should complete the form, on his or her own, by circling a subjective value for each symptom. This form can be used with each encounter to track progress toward symptom resolution. Many athletes may have some of these reported symptoms at a baseline, such as concentration difficulties in the patient with attention-deficit disorder or sadness in an athlete with underlying depression. This must be taken into consideration when interpreting the score. Athletes do not need a total score of 0 to return to play if they had symptoms before their concussion. This scale has not been validated to determine concussion severity.

Physical exertion and cognitive exertion, such as doing schoolwork, reading, playing video games, using a computer, and watching television, may worsen symptoms, although no link to long-term outcomes has been described. Athletes can develop symptoms during and after exertion, which indicates incomplete recovery.

INITIAL ASSESSMENT

On the Field

As with all acute head and neck injuries, initial assessment of the "ABCs" (airway, breathing, and circulation) and stabilization of the cervical spine are of the utmost importance. Cervical spine injury should be assumed in any athlete who is found to be unconscious after head or neck trauma. Maintaining adequate cervical spine stabilization is critical until neurologic function in all 4 limbs is evaluated and found to be intact and the athlete has no reported neck pain or cervical spine tenderness on palpation. If this evaluation cannot be accomplished or if a qualified medical professional is not available on the field, transport to an emergency facility is warranted. An athlete who was not unconscious or who quickly regained consciousness and is not suspected of having a cervical spine injury can be further evaluated on the sidelines.

Initial sideline evaluation should include an inquiry into the athlete's symptoms, a neurologic examination, and evaluation of the athlete's cognition by using one of several available sideline assessment tools, such as the Maddocks questions,[49] Standardized Assessment of Concussion (SAC),[50] Balance Error Scoring System (BESS),[51] or Sport Concussion Assessment Tool 2 (SCAT2).[5] The SCAT2 (Appendix 1) was released in the CIS Zurich statement as an enhanced version of the original SCAT introduced in the CIS Vienna statement and includes the majority of accepted sideline assessments in a comprehensive evaluation.[3,5]

The Maddocks questions are a brief set of questions to evaluate orientation as well as short- and long-term memory related to the sport and current game.[49] The questions are for sideline use only and are included in the SCAT2.[5] Examples of questions include "What team did you play last week?" and "Did the team win the last game?"

The BESS is an assessment of postural stability that is performed with the subject in 3 positions, first on a firm surface and then on a 10-cm-thick piece of foam. The 3 positions include standing flat on both feet with hands placed on the iliac crests, standing on a single leg on the nondominant foot, and standing flat on both feet with eyes closed. Each assessment lasts 20 seconds. A score is obtained by totaling the number of errors the athlete makes over the 6 tests.[51] The BESS seems to have a practice effect and also seems to be affected not only by the environment in which the test is conducted but also by how soon after exercise the test is given.[52–55] There are concerns of intra-rater and inter-rater reliability as well as determining the most reliable components of the individual tests.[56,57] On the basis of these studies, it seems beneficial to test an athlete more than 15 minutes after cessation of exercise and in a setting in which he or she will be doing follow-up assessments, rather than on the sideline.

The SAC has been shown to have little to no practice effect.[52,53] Baseline assessments with an SAC test can be helpful in interpreting postinjury results. Any decrease from the baseline score on an SAC was found to be 95% sensitive and 76% specific for a concussion.[58] The SAC has not been validated for use in the grade school athlete.

The newer SCAT2 incorporates both the BESS and the SAC; however, the full SCAT2 evaluation has not been researched since its release with the Zurich concussion statement. Because the SCAT2 has not yet been studied, the Zurich statement authors recommended relying on the SAC score until prospective studies are conducted on the SCAT2.[5]

If a concussion is identified, the athlete should be removed from the remainder of the practice or game(s) on that day.[5] The athlete should continue to be monitored for several hours after the injury to evaluate for any deterioration of his or her condition. Referral to the emergency department is warranted if an athlete experiences repeated vomiting, severe or progressively worsening headache, seizure activity, unsteady gait or slurred speech, weakness or numbness in the extremities, unusual behavior, signs of a basilar skull fracture, or altered mental status resulting in a Glasgow Coma Score of less than 15.

In the Office/Emergency Department

When the athlete is evaluated initially in the office or emergency department after a concussion, a thorough history, including signs and symptoms as well as details of any previous head injuries; head and neck examination; neurologic examination, including gait and balance assessment (such as the BESS, Romberg test, and tandem gait); and assessment of cognitive function, including relevant portions of the SAC or SCAT2, should be performed. Although the use of terms such as a "ding" or "getting your bell rung" has been discouraged because they may minimize the severity of the injury, athletes may be more inclined to give a positive history if those terms are used.[59] The athlete should also be monitored for any deterioration of his or her condition. If there is concern for a structural brain abnormality, neuroimaging should be considered. Athletes and their parents or caregivers should be instructed which signs and symptoms to follow when at home and given clear guidelines on what would necessitate a return to the emergency department or pediatrician's office.[60] Even if an athlete's symptoms clear on the same day of the concussion and the assessment in the office or emergency department is normal, the athlete should not be allowed to return to play that same day. There is still debate about whether periodically waking the athlete during the night is necessary, because there may be more benefit from uninterrupted sleep than frequent awakenings, which may exacerbate symptoms.

NEUROIMAGING

Conventional neuroimaging is typically normal in a concussive injury. Routine imaging using computed tomography (CT) or MRI contributes little to concussion evaluation and management.[5] Although rare, a concussive blow can be associated with a cervical spine injury, skull fracture, or any of the 4 types of intracranial hemorrhage (subdural, epidural, intracerebral, or subarachnoid).[61]

Neuroimaging should be considered whenever suspicion of an intracranial structural injury exists. Signs and symptoms that increase the index of suspicion for more serious injury include severe headache; seizures; focal neurologic findings on examination; repeated emesis; significant drowsiness or difficulty awakening; slurred speech; poor orientation to person, place, or time; neck pain; and significant irritability.[38] Any patient with worsening symptoms should also undergo neuroimaging. Patients with LOC for more than 30 seconds may have a higher risk of intracranial injury, so neuroimaging should be considered for them.[60] Normal neuroimaging results in the acute phase of injury may not rule out a chronic subdural hematoma or subsequent neurobehavioral dysfunction.[61]

CT is the test of choice to evaluate for intracranial hemorrhage during the first 24 to 48 hours after injury.[62,63] It is also a superior imaging modality for detection of skull fractures.[64] CT is faster, more cost-effective, and easier to perform than MRI. Although numerous criteria have been developed to guide neuroimaging decisions after head trauma, none are sensitive and specific enough to diagnose all intracranial pathology.[65–69]

A 2010 Canadian study evaluated clinical criteria to determine who may be at high risk of a structural brain injury identified on CT scan after a head injury.[70] Approximately 22% of the head injuries in this study were sport-related. Patients with a Glasgow Coma Scale score of less than 15 at 2 hours after injury, suspected open or depressed skull fracture, history of worsening headache, and irritability on examination were found to be at highest risk for a structural brain injury identified on a CT scan that needed neurosurgical intervention. One of the criteria for inclusion in this study was a witnessed LOC. Because LOC is noted in less than 10% of sport-related concussions, these criteria may not be applicable to all sport-related concussions.

MRI provides the ability to detect cerebral contusion, petechial hemorrhage, and white matter injury at a level superior to CT.[65] An MRI may be more appropriate if imaging is needed for an athlete 48 hours or longer after an injury and is best coordinated through the primary care or specialist physician evaluating the athlete. Newly emerging MRI modalities, such as gradient echo and perfusion and diffusion tensor imaging, are better than conventional MRI at detecting white matter alteration, especially in the pediatric population.[71,72] However, there is a paucity of research at this time that limits the clinical usefulness of these newer MRI modalities.

Functional imaging can be used to measure metabolic and hemodynamic changes in the brain.[71] Functional MRI is noninvasive and shows patterns that correlate with symptoms during concussion, such as more widespread brain activation while symptomatic compared with preinjury levels.[73] Other functional imaging modalities such as positron emission tomography (PET), magnetic resonance spectroscopy (MRS), and single-photon emission CT (SPECT) offer promise but are still in the early stages of development.[74] Functional neuroimaging will likely provide a more accurate picture of the injury and may help predict recovery better than structural neuroimaging, but further research and wider availability of this imaging modality is needed before it can be recommended.[74,75]

TABLE 4 Internet Resources

Computerized neuropsychological tests
US Army Medical Department, Automated Neuropsychological Assessment Metrics (ANAM): www.armymedicine.army.mil/prr/anam.html
CogState: www.cogstate.com/go/sport
Headminder: www.headminder.com
ImPACT: www.impacttest.com
Information on head injury
Centers for Disease Control and Prevention Heads Up Toolkit for High School Sports: www.cdc.gov/concussion/HeadsUp/high_school.html
Centers for Disease Control and Prevention Heads Up Toolkit for Schools: www.cdc.gov/concussion/HeadsUp/schools.html
Centers for Disease Control and Prevention Heads Up Toolkit for Physicians: www.cdc.gov/concussion/HeadsUp/physicians_tool_kit.html

NEUROPSYCHOLOGICAL TESTING

Neuropsychological testing has become more commonplace in the evaluation of the athlete with concussion as a means to provide an objective measure of brain function. Neuropsychological testing is one of several tools in the assessment of an athlete with concussion but does not independently determine if an athlete has experienced a concussion or when he or she may safely return to play.[3–5] Currently, testing is performed by using one of several computerized neuropsychological tests including ANAM (Automated Neuropsychological Assessment Metrics), CogState, HeadMinder, and ImPACT (see Table 4) or through pencil-and-paper testing administered by a neuropsychologist. ANAM was initially developed for use in the military, whereas the other tests were developed specifically for sport-related concussion.

Each of the computerized tests has published data on test-retest reliability, and all have demonstrated deficits in concussed athletes compared with their baseline assessments.[76–84] One critique of the computerized tests is that the vast majority of studies have been conducted by the developers of the tests, which raises some concern for bias, because some independent study results have suggested slightly less reliable results.[85,86] A few of these computerized tests have been widely adopted at all levels of sport participation.

More rigorous pencil-and-paper testing conducted formally by a neuropsychologist is also an option, although test-retest reliability has been questioned.[87] Given the large number of athletes with concussion and relative scarcity of neuropsychologists, accessibility to these providers may often be challenging and may not be covered by insurance carriers.[88] Although the clinical neuropsychologist is often the most experienced person to interpret neuropsychological tests, nonneuropsychologists may be trained to interpret them as well, which is an important advantage of the commercially available computerized tests.[89]

If computerized or pencil-and-paper neuropsychological testing is available, ideally a baseline or preinjury test should be obtained. Baseline testing is best performed before the start of the athlete's season. Testing should be performed in a quiet environment, free of noise or distractions, while the athlete is well rested rather than immediately after exercise. Many teams and schools will administer tests in computer laboratories proctored by a person with experience with the test, which allows for baseline testing of large groups of athletes over a short period of time.

There are no evidence-based guidelines or validated protocols about when to administer the computerized neuropsychological test after a concussion. Some administer the test while an athlete is symptomatic to provide objective data to the family and athlete regarding the injury and again when asymptomatic to help guide return to sport. Others administer the test only after an athlete has become asymptomatic to document that the athlete's cognitive function has returned to baseline. A symptomatic athlete should not be returned to play even with normal neuropsychological testing. If no baseline test is available for the athlete, his or her results can often be compared with age-established norms for the test. Interpretation of the tests should be performed by a neuropsychologist or physician who is experienced with these tests. Further research needs to be conducted to determine the optimum time and protocol for administering the computerized neuropsychological tests.

The optimum time frame for repeating baseline neuropsychological testing, if conducted, is still not well established, especially for the developing brain. A study that evaluated high school athletes with pencil-and-paper testing found stabilization of baseline scores between the 9th and 10th grades.[90] Another study of college athletes found stable scores over a 2-year period on a computerized test.[91] One must also consider that there is a lack of published baseline data in athletes younger than 12 years. There is currently no established, validated computerized neuropsychological test for the grade school athlete, although at the time of this clinical report, a computerized test for use in athletes younger than 12 years is being developed.

If an athlete is suffering from postconcussive symptoms over several months or has had multiple concussions, formal assessment by a neuropsychologist may be beneficial, specifically to identify areas for which the athlete may need academic accommodations.

MANAGEMENT

The goal of managing a young athlete with concussion is to hasten recovery by ensuring that the athlete is aware of and avoids activities and situations that may slow recovery. It is important to stress to patients and their parents to allow adequate time for full physical and cognitive recovery. Treating young athletes with a concussion is uniquely challenging, because their brains are still developing. Unfortunately, the lack of published data on the preadolescent athlete hinders evidence-based decision-making in this age group.[92] Also, there is a lack of consensus among physicians and certified athletic trainers as to how to evaluate and treat an athlete with concussion, despite widely available published guidelines.[88,93,94]

Medication Use

At the present time, there is currently no evidence-based research regarding the use of any medication in the treatment of the concussed pediatric athlete.[95] There is no evidence demonstrating the efficacy of the common use of nonsteroidal anti-inflammatory drugs (NSAIDs) or acetaminophen in alleviating the symptoms or shortening the course of an athlete's concussion. In 1 animal study, chronic administration of ibuprofen was found to worsen cognitive outcome after a traumatic brain injury.[96] It is commonly recommended that NSAIDs or aspirin be avoided immediately after a suspected head injury for fear of potentiating the risk of intracranial bleeding. Because no studies have documented any harm from use of NSAIDs after a sport-related concussion, this remains more of a theoretic risk.

Medication may be considered for those athletes with more prolonged symptoms such as difficulty concentrating, headache, sleep disturbances, and depression. Continued medication use to control concussion symptoms indicates incomplete recovery. Before considering a return to play, any medications used to reduce symptoms must be stopped and the athlete must remain symptom-free off medication.[5]

Cognitive Rest

Many athletes will report increased symptoms with cognitive activities after a concussion, which makes intuitive sense because the concussion is a functional rather than structural injury of the brain. Athletes with concussion often have difficulty attending school and focusing on schoolwork, taking tests, and trying to keep up with assignments, especially in math, science, and foreign-language classes. Reading, even for leisure, commonly worsens symptoms.

To prevent exacerbation of the athlete's symptoms and allow for continued recovery, "cognitive rest" is recommended. This rest may include a temporary leave of absence from school, shortening of the athlete's school day, reduction of workloads in school, and allowance of more time for the athlete to complete assignments or take tests. Taking standardized tests while recovering from a concussion should be discouraged, because lower-than-expected test scores may occur.[5,97] Test scores obtained while the athlete is recovering from concussion are likely not representative of true ability. Communication with school nurses, administrators, and teachers to be sure they understand these recommendations is imperative.

After reintegration into school, a student should be allowed adequate time to make up assignments, and the overall volume of make-up work should be reduced. Because students physically look well, it is not uncommon for teachers and other school officials to underestimate the difficulties that a student is experiencing and may downplay the need for cognitive rest. Education of teachers, counselors, and school administrators regarding the cognitive effects that a concussion may have on a student is important.

Other activities that require concentration and attention, including playing video games, using a computer, and viewing television, should also be discouraged, because they may exacerbate symptoms. If phonophobia is a significant symptom, exposure to loud music or the use of portable electronic music devices with headphones should be avoided. Sunglasses may be considered for athletes with significant photophobia.[98] Athletes often have slowed reaction times after a concussion and may need to avoid driving temporarily.

Physical Rest

After a concussion, all athletes should be withheld from physical exertion until they are asymptomatic at rest. With the proposed energy crisis in the brain,[13] increased energy demand in the brain from physical activity may exacerbate symptoms and has the potential to prolong recovery.[99] An athlete in the acute phase of a concussion should be restricted from physical activity. However, results of preliminary studies that evaluated patients with postconcussion syndrome have shown potential benefit from subsymptom threshold exercise training, which involves short durations of light cardiovascular activity without inducing symptoms.[100,101] Further research needs to be conducted before making formal recommendations regarding this treatment.

Broad restrictions of physical activity should be recommended, including not only the sport or activity that resulted in the concussion but also any weight training, cardiovascular training, physical education classes, and even sexual activity.[102] Leisure activities such as bike-riding, street hockey, and skateboarding should also be restricted, because they may impose a risk of additional head injury or symptom exacerbation. Assessment of mental health is also important, because a concussion may result in depression, in part from the injury itself but also from the prolonged time away from sports, difficulties in school, and sleep disturbances.

Recent Legislation

In May 2009, the state of Washington was first to pass a law regarding concussion management in young athletes. Also known as the Zackery Lystedt law, named after the then–13-year-old who sustained a serious head injury while playing football, this law requires school boards, in conjunction with the state interscholastic activity association, to develop educational materials and guidelines for athletes, coaches, and parents. The law also requires that parents and athletes sign an informed-consent form acknowledging the dangers of concussions before participation in sports. Finally, an athlete must be removed from any game if suspected of having a concussion and may not return until evaluated and given clearance to return to play from a licensed health care professional.[103] Many other states have subsequently either passed or are considering similar legislation.

RETURN TO PLAY

Determining when an athlete returns to play after a concussion should follow an individualized course, because each athlete will recover at a different pace. Under no circumstances should pediatric or adolescent athletes with concussion return to play the same day of their concussion. The phrase, "When in doubt, sit them out!" is paramount in the management of a pediatric or adolescent concussion.[3] No athlete should return to play while still symptomatic at rest or with exertion. Although the vast majority of athletes with concussion will become asymptomatic within a week of their concussion, numerous studies have demonstrated a longer recovery of full cognitive function in younger athletes compared with college-aged or professional athletes[104–108]—often 7 to 10 days or longer.[109] Because of this longer cognitive recovery period, although they are asymptomatic, there should be a more conservative approach to deciding when pediatric and adolescent athletes can return to play.

Concussion Rehabilitation

Initially proposed in 2000 by the Canadian Academy of Sport Medicine and endorsed by the CIS group in Vienna, a graded return-to-play protocol after a concussion is recommended.[3,110] This may also be referred to as "concussion rehabilitation." Once asymptomatic at rest, the athlete progresses in a stepwise fashion (Table 5) through the protocol as long as he or she remains asymptomatic. This progress may be monitored by the parent or an athletic trainer if proper instructions are given on how to proceed. Each step should take at least 24 hours, and it will take an athlete a minimum of 5 days to progress through the protocol to resume full game participation, provided symptoms do not return. A return of symptoms indicates inadequate recovery from the concussion. If symptoms return while on the protocol, once the athlete is asymptomatic again for 24 hours, the previous step may be at-

TABLE 5 Concussion Rehabilitation/Stepwise Return to Play

Rehabilitation Stage	Functional Exercise
1. No activity	Complete physical and cognitive rest
2. Light aerobic activity	Walking, swimming, stationary cycling at 70% maximum heart rate; no resistance exercises
3. Sport-specific exercise	Specific sport-related drills but no head impact
4. Noncontact training drills	More complex drills, may start light resistance training
5. Full-contact practice	After medical clearance, participate in normal training
6. Return to play	Normal game play

Each stage in concussion rehabilitation should last no less than 24 hours with a minimum of 5 days required to consider a full return to competition. If symptoms recur during the rehabilitation program, the athlete should stop immediately. Once asymptomatic after at least another 24 hours, the athlete should resume at the previous asymptomatic level and try to progress again. Athletes should contact their health care provider if symptoms recur. Any athlete with multiple concussions or prolonged symptoms may require a longer concussion-rehabilitation program, which is ideally created by a physician who is experienced in concussion management.

tempted again. Any athlete who continues to have a return of symptoms with exertion should be reevaluated by his or her health care provider. An athlete who has recovered from prolonged postconcussion syndrome or with a history of multiple concussions may need a longer period of time to progress through each step.

PREVENTION

Although preventing all concussions is unlikely, many attempts have been made to reduce the risk of concussion for athletes. These attempts include modifications to protective gear, rule changes, trying to identify athletes at risk, and continuing to educate everyone involved with youth and high school sports about the dangers of concussions.

Mouth Guards

The use of mouth guards for reducing the risk of dental trauma is well established. The role of the mouth guard in preventing concussions is more controversial. Although several studies have evaluated various mouth guards, none have conclusively demonstrated that mouth guards reduce the risk of concussion.[111–116]At this point in time, mouth guards are recommended to reduce dental trauma, but further studies are needed to evaluate their role in reducing the risk of concussions.

Helmets/Headgear

Helmets in sports have been shown in laboratory studies to reduce impact forces to the head. However, reduction in concussion incidence has not been consistently seen, despite the use of helmets. One study evaluated newer football helmet technology in high school athletes, which demonstrated a 31% decrease in relative risk and 2.3% decrease in absolute risk for sustaining a concussion.[117] Laboratory studies of a newer helmet technology suggest a potential 10% decrease in risk of reproduced concussion hits.[118] Continued technologic advances should be applauded, but further independent research and evaluation of these advances is necessary before they can be reported to reduce concussion incidence. Helmets should be assessed to meet the requirements of the National Operating Committee on Standards for Athletic Equipment for newly constructed or reconditioned helmets and should be appropriately fit for each individual athlete.

Helmets have been demonstrated to reduce concussion incidence in skiing and snowboarding and are recommended for these sports.[119–121] In a study of concussed hockey players wearing helmets with full face shields compared with half-face shield helmets, players wearing the full face shield helmet returned to play sooner, but there was no demonstrated decrease in risk or incidence of concussion between the 2 groups.[122]

Results of soccer headgear studies have revealed mild protection from concussion from players colliding heads but not from heading the ball.[123] Headgear seems to protect against soft-tissue injuries, such as lacerations, contusions, and abrasions, and is more likely to be worn by female soccer players.[123,124] Most studies have been found to have significant limitations in evaluating the potential for reducing concussions.[125] Prospective data are not currently sufficient to support recommending universal use of headgear in soccer.[126] Heading the ball in soccer is felt to be safe, if performed properly.[126] Avoiding heading does not prevent concussions.[126]

Genetic Testing

The presence of genetic markers (eg, apolipoprotein E4 gene, S-100 calcium-binding protein gene) and neuron-specific enolase have been evaluated as possible predisposing risk factors for concussion. However, the few studies conducted on younger athletes have not demonstrated significant differences in head injury characteristics or outcomes of athletes who possess these genetic markers.[127–129]At this time, genetic testing is not recommended for evaluating young athletes with concussion.

Education

Education and recognition remain the most important components of improving the care of athletes with concussions. Education should target all the key individuals involved, including athletes, parents, coaches, school administrators, athletic directors, teachers, athletic trainers, physicians, and other health care providers. Previous studies have demonstrated poor knowledge of concussion recognition and management by players, coaches, and even clinicians.[130–133]

In 2005, the Centers for Disease Control and Prevention (CDC) published a series of concussion toolkits, titled "Heads Up," for coaches, practicing clinicians, teachers, and school counselors. These toolkits are available free from the CDC via the Internet.[134] A survey of coaches showed high satisfaction with the CDC toolkit.[135]

COMPLICATIONS

Long-term Effects

The long-term effects of concussions in athletes of all ages are cause for considerable concern. With a lack of long-term prospective studies in high school and younger athletes who sustained concussions, there are more questions than conclusive answers. An 18-year-old multisport athlete with a history of concussions from football was reported to have autopsy findings of chronic traumatic encephalopathy, previously only reported in professional football players and professional boxers.[136,137]

Athletes with 3 or more concussions are more likely to have had LOC, postevent amnesia, confusion, and 3 to 4 abnormal on-field markers of concussion.[138] Three months after a concussion, children 8 to 16 years of age have been found to have persistent deficits in processing complex visual stimuli.[139] Athletes with 2 or more concussions who had not been concussed in the previous 6 months performed similarly on neuropsychological testing as did athletes without a history of concussions who were concussed within in the previous week.[140] Compared with similar students without a history of concussion, athletes with 2 or more concussions also demonstrate statistically significant lower grade-point averages.[140] More research is needed to investigate the long-term effects of concussions at all ages of childhood and adolescence.

Second-Impact Syndrome

Second-impact syndrome occurs when an athlete who has sustained an initial head injury sustains a second head injury before the symptoms associated with the first have fully cleared. Second-impact syndrome results in cerebral vascular congestion, which often can progress to diffuse cerebral swelling and death.[141]

Although there is debate whether the cerebral swelling is attributable to 2 separate hits or a single hit, there is no question that pediatric and adolescent athletes seem to be at the highest risk of this rare condition, because all reported cases are of athletes younger than 20 years.[142] In addition, since 1945, more than 90% of the head injury–related fatalities from sports recorded by the National Center for Catastrophic Sports Injury Research occurred in athletes in high school or younger.[143] Catastrophic football head injuries are 3 times more likely to occur in high school athletes than in college athletes.[144]

Postconcussion Syndrome

A clear definition for postconcussion syndrome does not exist. The World Health Organization (WHO) established a definition of the presence of 3 or more of the following symptoms after a head injury: headache; dizziness; fatigue; irritability; difficulty with concentrating and performing mental tasks; impairment of memory; insomnia; and reduced tolerance to stress, emotional excitement, or alcohol.[145] However, the WHO definition does not specify a minimum duration of these symptoms to make the diagnosis.

Postconcussion syndrome is defined in the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* as 3 months' duration of 3 or more of the following symptoms: fatigue; disordered sleep; headache; vertigo/dizziness; irritability or aggressiveness; anxiety or depression; personality changes; and/or apathy. Younger patients often demonstrate significant decline in school performance. Neuropsychological testing usually demonstrates difficulty in attention or memory.[146]

A recently proposed definition of postconcussive syndrome is the presence of cognitive, physical, or emotional symptoms of a concussion lasting longer than expected, with a threshold of 1 to 6 weeks of persistent symptoms after a concussion to make the diagnosis.[147]

Retirement From Sports

As with determining return to play, determining when to retire an athlete from 1 or multiple sports is often difficult for all involved. No evidence-based guidelines exist for the consideration of retiring an athlete from a sport.[148] It has been proposed that any athlete who has sustained 3 concussions in an individual season or has had postconcussive symptoms for more than 3 months should be strongly considered for a prolonged period of time away from sports.[149,150] If a clinician is not comfortable making a determination about the length of time to withhold the athlete from sports or is contemplating permanent removal from sports, referral to a specialist with expertise in sport-related concussion is recommended.

CONCLUSIONS AND GUIDANCE FOR CLINICIANS

1. Sport-related concussions are common in youth and high school sports. Limited data are available on concussions in grade school athletes, and further research is needed.
2. Concussion has many signs and symptoms, some of which overlap

with other medical conditions. LOC is uncommon, and if it lasts longer than 30 seconds, it may indicate more significant intracranial injury.

3. Results of structural neuroimaging, such as CT or MRI, generally are normal with a concussion.
4. Neuropsychological testing can be helpful to provide objective data to athletes and their families after a concussion. Neuropsychological testing is 1 tool in the complete management of a sport-related concussion and alone does not make a diagnosis or determine when return to play is appropriate.
5. Athletes with concussion should rest, both physically and cognitively, until their symptoms have resolved both at rest and with exertion. Teachers and school administrators should work with students to modify workloads to avoid exacerbation of symptoms.
6. The signs and symptoms of a concussion typically resolve in 7 to 10 days in the majority of cases. Some athletes, however, may take weeks to months to recover.
7. Any pediatric or adolescent athlete who sustains a concussion should be evaluated by a health care professional, ideally a physician with experience in concussion management, and receive medical clearance before returning to play.
8. Pediatric and adolescent athletes should never return to play while symptomatic at rest or with exertion. Athletes also should not be returned to play on the same day of the concussion, even if they become asymptomatic. The recovery course is longer for younger athletes than for college and professional athletes, and a more conservative approach to return to play is warranted.
9. The long-term effects of concussion are still relatively unknown, and further longitudinal research is needed to offer further guidance to athletes of all ages.
10. Education about sport-related concussion is integral to helping improve awareness, recognition, and management.
11. The safety and efficacy of medications in the management of sport-related concussion has not been established.
12. Retirement from contact or collision sports may be necessary for the athlete with a history of multiple concussions or with long symptomatic courses after his or her concussion.
13. New evidence-based protocols for the diagnosis and management of concussion should be incorporated into pediatric training modules and competencies.

LEAD AUTHORS

Mark E. Halstead, MD
Kevin D. Walter, MD

COUNCIL ON SPORTS MEDICINE AND FITNESS EXECUTIVE COMMITTEE, 2009–2010

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Lisa K. Kluchurosky, MEd, ATC – *National Athletic Trainers Association*
John F. Philpott, MD – *Canadian Paediatric Society*
Kevin D. Walter, MD – *National Federation of State High School Associations*

CONSULTANTS

Michael F. Bergeron, PhD
Greg L. Landry, MD
Kelsey Logan, MD

STAFF

Anjie Emanuel, MPH
aemanuel@aap.org

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SCAT2

Sport Concussion Assessment Tool 2

Name

Sport/team

Date/time of injury

Date/time of assessment

Age   Gender M F

Years of education completed

Examiner

What is the SCAT2?[1]

This tool represents a standardized method of evaluating injured athletes for concussion and can be used in athletes aged from 10 years and older. It supersedes the original SCAT published in 2005[2]. This tool also enables the calculation of the Standardized Assessment of Concussion (SAC)[3,4] score and the Maddocks questions[5] for sideline concussion assessment.

Instructions for using the SCAT2

The SCAT2 is designed for the use of medical and health professionals. Preseason baseline testing with the SCAT2 can be helpful for interpreting post-injury test scores. Words in Italics throughout the SCAT2 are the instructions given to the athlete by the tester.

This tool may be freely copied for distribtion to individuals, teams, groups and organizations.

What is a concussion?

A concussion is a disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific symptoms (like those listed below) and often does not involve loss of consciousness. Concussion should be suspected in the presence of **any one or more** of the following:

- Symptoms (such as headache), or
- Physical signs (such as unsteadiness), or
- Impaired brain function (e.g. confusion) or
- Abnormal behaviour.

Any athlete with a suspected concussion should be REMOVED FROM PLAY, medically assessed, monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle.

Symptom Evaluation

How do you feel?

You should score yourself on the following symptoms, based on how you feel now.

	none	mild		moderate		severe	
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck Pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Blurred vision	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Sensitivity to light	0	1	2	3	4	5	6
Sensitivity to noise	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Feeling like "in a fog"	0	1	2	3	4	5	6
"Don't feel right"	0	1	2	3	4	5	6
Difficulty concentrating	0	1	2	3	4	5	6
Difficulty remembering	0	1	2	3	4	5	6
Fatigue or low energy	0	1	2	3	4	5	6
Confusion	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Trouble falling asleep (if applicable)	0	1	2	3	4	5	6
More emotional	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Nervous or Anxious	0	1	2	3	4	5	6

Total number of symptoms (Maximum possible 22)

Symptom severity score

(Add all scores in table, maximum possible: 22 x 6 = 132)

Do the symptoms get worse with physical activity? Y N

Do the symptoms get worse with mental activity? Y N

Overall rating

If you know the athlete well prior to the injury, how different is the athlete acting compared to his / her usual self? Please circle one response.

no different	very different	unsure

APPENDIX 1

THE SCAT2.

Cognitive & Physical Evaluation

1 Symptom score (from page 1)

22 **minus** number of symptoms — of 22

2 Physical signs score

Was there loss of consciousness or unresponsiveness?	Y	N
If yes, how long? ____ minutes		
Was there a balance problem/unsteadiness?	Y	N

Physical signs score (1 point for each negative response) — of 2

3 Glasgow coma scale (GCS)

Best eye response (E)	
No eye opening	1
Eye opening in response to pain	2
Eye opening to speech	3
Eyes opening spontaneously	4
Best verbal response (V)	
No verbal response	1
Incomprehensible sounds	2
Inappropriate words	3
Confused	4
Oriented	5
Best motor response (M)	
No motor response	1
Extension to pain	2
Abnormal flexion to pain	3
Flexion/Withdrawal to pain	4
Localizes to pain	5
Obeys commands	6
Glasgow Coma score (E + V + M)	of 15

GCS should be recorded for all athletes in case of subsequent deterioration.

4 Sideline Assessment – Maddocks Score

"I am going to ask you a few questions, please listen carefully and give your best effort."

Modified Maddocks questions (1 point for each correct answer)

At what venue are we at today?	0	1
Which half is it now?	0	1
Who scored last in this match?	0	1
What team did you play last week/game?	0	1
Did your team win the last game?	0	1

Maddocks score — of 5

Maddocks score is validated for sideline diagnosis of concussion only and is not included in SCAT 2 summary score for serial testing.

5 Cognitive assessment

Standardized Assessment of Concussion (SAC)

Orientation (1 point for each correct answer)

What month is it?	0	1
What is the date today?	0	1
What is the day of the week?	0	1
What year is it?	0	1
What time is it right now? (within 1 hour)	0	1

Orientation score — of 5

Immediate memory

"I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order."

Trials 2 & 3:

"I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before."

Complete all 3 trials regardless of score on trial 1 & 2. Read the words at a rate of one per second. Score 1 pt. for each correct response. Total score equals sum across all 3 trials. Do not inform the athlete that delayed recall will be tested.

List	Trial 1		Trial 2		Trial 3		Alternative word list		
elbow	0	1	0	1	0	1	candle	baby	finger
apple	0	1	0	1	0	1	paper	monkey	penny
carpet	0	1	0	1	0	1	sugar	perfume	blanket
saddle	0	1	0	1	0	1	sandwich	sunset	lemon
bubble	0	1	0	1	0	1	wagon	iron	insect
Total									

Immediate memory score — of 15

Concentration

Digits Backward:

"I am going to read you a string of numbers and when I am done, you repeat them back to me backwards, in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7."

If correct, go to next string length. If incorrect, read trial 2. One point possible for each string length. Stop after incorrect on both trials. The digits should be read at the rate of one per second.

			Alternative digit lists		
4-9-3	0	1	6-2-9	5-2-6	4-1-5
3-8-1-4	0	1	3-2-7-9	1-7-9-5	4-9-6-8
6-2-9-7-1	0	1	1-5-2-8-6	3-8-5-2-7	6-1-8-4-3
7-1-8-4-6-2	0	1	5-3-9-1-4-8	8-3-1-9-6-4	7-2-4-8-5-6

Months in Reverse Order:

"Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November ... Go ahead"

1 pt. for entire sequence correct

Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr-Mar-Feb-Jan	0	1

Concentration score — of 5

[1] This tool has been developed by a group of international experts at the 3rd International Consensus meeting on Concussion in Sport held in Zurich, Switzerland in November 2008. The full details of the conference outcomes and the authors of the tool are published in British Journal of Sports Medicine, 2009, volume 43, supplement 1.
The outcome paper will also be simultaneously co-published in the May 2009 issues of Clinical Journal of Sports Medicine, Physical Medicine & Rehabilitation, Journal of Athletic Training, Journal of Clinical Neuroscience, Journal of Science & Medicine in Sport, Neurosurgery, Scandinavian Journal of Science & Medicine in Sport and the Journal of Clinical Sports Medicine.

[2] McCrory P et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. British Journal of Sports Medicine. 2005; 39: 196-204

[3] McCrea M. Standardized mental status testing of acute concussion. Clinical Journal of Sports Medicine. 2001; 11: 176-181

[4] McCrea M, Randolph C, Kelly J. Standardized Assessment of Concussion: Manual for administration, scoring and interpretation. Waukesha, Wisconsin, USA.

[5] Maddocks, DL; Dicker, GD; Saling, MM. The assessment of orientation following concussion in athletes. Clin J Sport Med. 1995;5(1):32–3

[6] Guskiewicz KM. Assessment of postural stability following sport-related concussion. Current Sports Medicine Reports. 2003; 2: 24-30

APPENDIX 1
Continued.

6 Balance examination

This balance testing is based on a modified version of the Balance Error Scoring System (BESS)[6]. A stopwatch or watch with a second hand is required for this testing.

Balance testing

"I am now going to test your balance. Please take your shoes off, roll up your pant legs above ankle (if applicable), and remove any ankle taping (if applicable). This test will consist of three twenty second tests with different stances."

(a) Double leg stance:
"The first stance is standing with your feet together with your hands on your hips and with your eyes closed. You should try to maintain stability in that position for 20 seconds. I will be counting the number of times you move out of this position. I will start timing when you are set and have closed your eyes."

(b) Single leg stance:
"If you were to kick a ball, which foot would you use? [This will be the dominant foot] *Now stand on your non-dominant foot. The dominant leg should be held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."*

(c) Tandem stance:
"Now stand heel-to-toe with your ***non-dominant foot*** *in back. Your weight should be evenly distributed across both feet. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."*

Balance testing – types of errors

1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into > 30 degrees abduction
5. Lifting forefoot or heel
6. Remaining out of test position > 5 sec

Each of the 20-second trials is scored by counting the errors, or deviations from the proper stance, accumulated by the athlete. The examiner will begin counting errors only after the individual has assumed the proper start position. **The modified BESS is calculated by adding one error point for each error during the three 20-second tests. The maximum total number of errors for any single condition is 10.** If a athlete commits multiple errors simultaneously, only one error is recorded but the athlete should quickly return to the testing position, and counting should resume once subject is set. Subjects that are unable to maintain the testing procedure for a minimum of **five seconds** at the start are assigned the highest possible score, ten, for that testing condition.

Which foot was tested: ☐ Left ☐ Right
(i.e. which is the **non-dominant** foot)

Condition	Total errors
Double Leg Stance (feet together)	of 10
Single leg stance (non-dominant foot)	of 10
Tandem stance (non-dominant foot at back)	of 10
Balance examination score (30 **minus** total errors)	of 30

7 Coordination examination

Upper limb coordination

Finger-to-nose (FTN) task: ***"I am going to test your coordination now. Please sit comfortably on the chair with your eyes open and your arm (either right or left) outstretched (shoulder flexed to 90 degrees and elbow and fingers extended). When I give a start signal, I would like you to perform five successive finger to nose repetitions using your index finger to touch the tip of the nose as quickly and as accurately as possible."***

Which arm was tested: ☐ Left ☐ Right

Scoring: 5 correct repetitions in < 4 seconds = 1

Note for testers: Athletes fail the test if they do not touch their nose, do not fully extend their elbow or do not perform five repetitions. Failure should be scored as 0.

Coordination score of 1

8 Cognitive assessment

Standardized Assessment of Concussion (SAC)

Delayed recall

"Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order."

Circle each word correctly recalled. Total score equals number of words recalled.

List	Alternative word list		
elbow	candle	baby	finger
apple	paper	monkey	penny
carpet	sugar	perfume	blanket
saddle	sandwich	sunset	lemon
bubble	wagon	iron	insect

Delayed recall score of 5

Overall score

Test domain	Score
Symptom score	of 22
Physical signs score	of 2
Glasgow Coma score (E + V + M)	of 15
Balance examination score	of 30
Coordination score	of 1
Subtotal	**of 70**
Orientation score	of 5
Immediate memory score	of 5
Concentration score	of 15
Delayed recall score	of 5
SAC subtotal	**of 30**
SCAT2 total	**of 100**
Maddocks Score	**of 5**

Definitive normative data for a SCAT2 "cut-off" score is not available at this time and will be developed in prospective studies. Embedded within the SCAT2 is the SAC score that can be utilized separately in concussion management. The scoring system also takes on particular clinical significance during serial assessment where it can be used to document either a decline or an improvement in neurological functioning.

Scoring data from the SCAT2 or SAC should not be used as a stand alone method to diagnose concussion, measure recovery or make decisions about an athlete's readiness to return to competition after concussion.

APPENDIX 1
Continued.

Athlete Information

Any athlete suspected of having a concussion should be removed from play, and then seek medical evaluation.

Signs to watch for

Problems could arise over the first 24-48 hours. You should not be left alone and must go to a hospital at once if you:

- Have a headache that gets worse
- Are very drowsy or can't be awakened (woken up)
- Can't recognize people or places
- Have repeated vomiting
- Behave unusually or seem confused; are very irritable
- Have seizures (arms and legs jerk uncontrollably)
- Have weak or numb arms or legs
- Are unsteady on your feet; have slurred speech

Remember, it is better to be safe.
Consult your doctor after a suspected concussion.

Return to play

Athletes should not be returned to play the same day of injury. When returning athletes to play, they should follow a stepwise symptom-limited program, with stages of progression. For example:

1. rest until asymptomatic (physical and mental rest)
2. light aerobic exercise (e.g. stationary cycle)
3. sport-specific exercise
4. non-contact training drills (start light resistance training)
5. full contact training after medical clearance
6. return to competition (game play)

There should be approximately 24 hours (or longer) for each stage and the athlete should return to stage 1 if symptoms recur. Resistance training should only be added in the later stages.
Medical clearance should be given before return to play.

Tool		Test domain	Time	Score			
			Date tested				
			Days post injury				
SCAT2		Symptom score					
		Physical signs score					
		Glasgow Coma score (E + V + M)					
		Balance examination score					
		Coordination score					
	SAC	Orientation score					
		Immediate memory score					
		Concentration score					
		Delayed recall score					
		SAC Score					
Total		**SCAT2**					
Symptom severity score (max possible 132)							
Return to play				☐ Y ☐ N	☐ Y ☐ N	☐ Y ☐ N	☐ Y ☐ N

Additional comments

Concussion injury advice (To be given to concussed athlete)

This patient has received an injury to the head. A careful medical examination has been carried out and no sign of any serious complications has been found. It is expected that recovery will be rapid, but the patient will need monitoring for a further period by a responsible adult. Your treating physician will provide guidance as to this timeframe.

If you notice any change in behaviour, vomiting, dizziness, worsening headache, double vision or excessive drowsiness, please telephone the clinic or the nearest hospital emergency department immediately.

Other important points:

- **Rest and avoid strenuous activity for at least 24 hours**
- **No alcohol**
- **No sleeping tablets**
- **Use paracetamol or codeine for headache. Do not use aspirin or anti-inflammatory medication**
- **Do not drive until medically cleared**
- **Do not train or play sport until medically cleared**

Clinic phone number

Patient's name

Date/time of injury

Date/time of medical review

Treating physician

Contact details or stamp

APPENDIX 1
Continued.

Sport-Related Concussion in Children and Adolescents

Mark E. Halstead, Kevin D. Walter and The Council on Sports Medicine and Fitness

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