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Dr Giza has served as a consultant for Alcobra Pharma and Pearson PLC and as a consultant on patient referrals for Major League Soccer, the National Football League, and the National Hockey League Players Association; he serves on committees of Major League Soccer and the National Collegiate Athletic Association and on the data safety monitoring board of LA Biomed. Dr Giza serves as a speaker for the Medical Education Speakers Network; has given expert testimony on medicolegal cases; receives book royalties from Blackwell Publishing; receives payment for the development of educational presentations from American Physician Institute, the AAN, and the University of California, Los Angeles; and received travel and/or accommodations and/or meeting expenses from the AAN, California State Athletic Commission, Major League Soccer, and the National Collegiate Athletic Association.

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Pediatric Issues in Sports Concussions

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ABSTRACT

Purpose of Review: Sports-related concussions are receiving increasing attention in both the lay press and medical literature. While most media attention has been on high-profile collegiate or professional athletes, the vast majority of individuals participating in contact and collision sports are adolescents and children. This review provides a practical approach toward youth sports-related concussion with a foundation in the recent guidelines, but including specific considerations when applying these management principles to children and adolescents.

Recent Findings: Objective measurement of early signs and symptoms is challenging in younger patients, and many commonly used assessment tools await rigorous validation for younger patients. Excellent evidence-based guidelines exist for CT evaluation of mild traumatic brain injury presenting to the emergency department. Evidence suggests that recovery from sports-related concussion takes longer in high school athletes compared with collegiate or professionals; however, rigorous studies below high school age are still lacking.

Summary: Proper care for concussion in youth requires a delicate balance of clinical skills, age-appropriate assessment, and individualized management to achieve optimal outcomes.

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INTRODUCTION

Sports-related concussions are receiving increasing attention in both the lay press and medical literature, from *The New York Times* and *Sports Illustrated* to Institute of Medicine reports. While most media attention has been on high-profile collegiate or professional athletes, the vast majority of individuals participating in contact and collision sports are adolescents and children. Several recent guidelines have been published for management of sports-related concussion, using both evidence-based and consensus- and expert-based methods^{1–4} and including recommendations for concussions occurring in the pediatric population. (Refer to Appendix A for a summary of the American Academy of Neurology's evidence-based guideline for clinicians.)

In general, objective measurement of early signs and symptoms is chal-

lenging in younger patients, and many commonly used assessment tools await rigorous validation for younger patients. Excellent evidence-based guidelines exist for CT evaluation of mild traumatic brain injury (TBI) presenting to the emergency department, but the majority of sports-related concussions may only present in clinic or urgent care.⁵ Published evidence suggests that recovery from sports-related concussion takes longer in high school athletes compared with collegiate or professionals; however, rigorous studies below high school age are still lacking.

Epidemiology

Sports-related concussions are increasingly viewed as a major public health concern, with estimates of 1.6 to 3.8 million such injuries annually in the

United States.⁶ Significant increases in rates of reported concussions have been described in collegiate (National Collegiate Athletic Association),⁷ high school,⁸ and younger students.⁹ Based on these numbers, sports neurologists and other clinical care providers who manage sports-related concussions need to be aware of age-specific issues and other challenges when taking care of pediatric and adolescent student athletes.

Definitions

A concussion has been defined as a complex pathophysiologic response to biomechanical forces imparted to the brain, resulting in onset of neurologic symptoms that predominantly reflect a functional disturbance, rather than a gross structural injury.^{3,4} While it is largely synonymous with mild TBI, the term mild TBI has historically arisen from a Glasgow Coma Scale score of 13 to 15, which can occur with or without demonstrable macrostructural injury on acute neuroimaging. Concussions or mild TBIs can happen in many circumstances (eg, accidents, falls, sports, and recreation) and, for the most part, the definitions and pathophysiology are not unique to sports- or non-sports-related injury. An important distinction of a sports-related concussion is the implicit assumption that the athlete will purposely be returning to contact risk.

More recently, the term subconcussive injury has been used to describe evidence of neural dysfunction after contact sport exposure in the absence of symptoms.¹ This terminology has been used almost exclusively in studies of contact and collision sports, where biomechanical impacts are routinely sustained repetitively over a short period of time. Obviously, gray areas exist between organized contact sports and general unstructured play, although the risks of recurrent injury are likely different and practicality prohibits systematically limiting unstructured play

in the manner possible for supervised sports participation.

Distinctions in terminology regarding chronic postconcussion impairments are also worth knowing. Postconcussion syndrome typically refers to new-onset symptoms that persist after a concussion, and chronic postconcussion syndrome has been used to refer to an uncommon scenario of unresolving postconcussion syndrome.¹⁰ The term chronic neurocognitive impairment was introduced in the American Medical Society for Sports Medicine's concussion guidelines to refer to either chronic postconcussion syndrome or late-emerging deficits on neuropsychological testing.² These clinical diagnoses are distinct from chronic traumatic encephalopathy (CTE), a term used to describe autopsy-proven cases of abnormal tau deposition seen in some athletes and military personnel with prior history of concussions or contact/collision sport exposure.¹¹

Legislation

While identification and management of concussions has been the focus of public debate in professional and collegiate sports for several years, an added factor of concussion legislation is present in youth sports. With active legislation in all 50 states, practitioners caring for children and adolescents are advised to keep current with the legal requirements in their state. In general, concussion legislation has evolved from the Zackery Lystedt law in Washington state, and contains three main components: (1) mandatory education of athletes, parents, and coaches; (2) removal from play or practice if a concussion is suspected; and (3) evaluation and clearance by a licensed health care provider before returning to play. Details of state concussion laws can be found in the AAN Sports Concussion Toolkit.¹² (For a complete list of resources included in the Sports Concussion Toolkit, see **Appendix B**.)

KEY POINTS

- A concussion is a complex pathophysiologic response to biomechanical forces imparted to the brain, resulting in the onset of neurologic symptoms that predominantly reflect a functional disturbance, rather than a gross structural injury.
- Most current youth concussion legislation has the following three main components: (1) mandatory education of athletes, parents, and coaches; (2) removal from play or practice if a concussion is suspected; and (3) evaluation and clearance by a licensed health care provider before returning to play.

KEY POINTS

- In comparable sports such as soccer, basketball, softball, and baseball, girls have a higher rate of concussions than boys. Cheerleading is also a cause of concussions that is sometimes overlooked.
- Sports with the highest risk for concussion in boys are football, ice hockey, and lacrosse, followed by soccer, wrestling, and basketball. In girls, soccer, ice hockey, and lacrosse have the highest risk, followed by basketball, field hockey, softball, and gymnastics.

RISK FACTORS FOR YOUTH CONCUSSIONS

Age

Currently, insufficient data exist to determine whether age affects risk of sustaining a concussion, and it is difficult to separate age from level of play in most studies. Some factors, such as larger head-to-body ratio, weaker neck muscles, increased brain metabolic requirements, incomplete myelination, and thinner skull, might suggest that younger individuals are more vulnerable. Factors such as reduced body weight and mass in collisions, different rules, and greater plasticity might indicate reduced risks in younger individuals. While age does not clearly affect risk of sustaining a concussion, several studies indicate that high school athletes have more persistent neurocognitive dysfunction than collegiate or adult athletes.^{13,14} This suggests that younger athletes may be at risk for more prolonged concussion recovery times.

Sex

Recent studies of high school athletes indicate that females have a higher risk of sustaining a concussion than males in sports that have comparable rules between sexes, such as basketball, soccer, baseball, and softball.^{8,15} Female ice hockey players also show higher concussion rates than males at the collegiate level, but high school and youth data for ice hockey are lacking. These sex differences may be related to reduced neck musculature. Other explanations include different symptom-reporting rates and hormonal distinctions between sexes, but evidence for these is less compelling. Prior studies have been inconclusive in terms of severity or duration of symptoms, although recent work has suggested worse postconcussion impairments in females, especially after correcting for body mass index.^{13,16}

Level and Type of Sport

Risks of concussion are greater in collegiate sports than high school,^{1,3} but concussion risks for junior high or grade school have not been reported. Another important limitation is a lack of research on youth sports-related concussion outside of academic settings, such as intramural or club sports. Concussion risk is generally greater in competition compared with practice settings across many sports.¹⁵ In boys, sports with the highest risk for concussion include football, ice hockey, and lacrosse, followed by soccer, wrestling, and basketball. In girls, soccer, ice hockey, and lacrosse have the highest risks, followed by basketball, field hockey, softball, and gymnastics (**Case 3-1**).^{8,15} More recently, activities such as cheerleading are being recognized as sports and have also reported risks for concussions.

Athlete-Specific Factors

Multiple studies have shown that history of a prior concussion or TBI is associated with an increased risk for another concussion.^{17–20} Some studies suggest that a greater number of concussions is associated with more severe or prolonged symptoms or neurocognitive impairment after subsequent concussions.^{20,21}

Currently, no data exist to indicate whether a particular genetic marker is associated with an increased risk of concussion. Different genetic markers have been associated with cerebral edema after mild TBI or chronic cognitive impairment, and the pediatric implications of these will be discussed later in this article.

Equipment

No conclusive evidence exists that a particular helmet prevents clinical concussions better than others. The vast majority of football helmet comparative

Case 3-1

A 16-year-old boy was seen for a preparticipation examination. A careful sports history was conducted, and a graded symptom checklist, cognitive and balance assessment, and neurologic examination were completed. He had a past history of at least one prior diagnosed concussion and was active in several sports, including football, soccer, and track. He had few baseline symptoms and a normal cognitive, balance, and neurologic examination. He and his parents were worried about his risk of getting a concussion. Preparticipation counseling included explaining the definition of concussion, known (and unknown) risks for both concussion and persistent neurocognitive impairments, and benefits of sports participation. This was followed by an individualized discussion relevant to the particular student athlete's circumstances so that his family could make an informed decision based upon existing facts.

Comment. The main proven risk factors for sustaining a concussion are sex, type of sport, prior history of concussion, and whether the event is full competition versus practice. No specific type of helmet is better than others at preventing concussions. Likewise, no position has been proven to be more or less vulnerable to concussions. The number of years playing contact sports may be a risk factor for chronic impairments seen in professional contact athletes, but by itself does not confer an additional risk for sustaining a concussion. Lastly, cognitive ability as assessed by grade point average does not predict either risk for concussion or severity of symptoms after a concussion. This student athlete played football, which is a high-risk sport for concussion, and soccer, a moderate-risk sport. He had had one prior concussion, which occurred several years ago with full recovery. His academic performance was good, and both he and his parents appreciated benefits from his sports participation.

His parents could minimize his risk in participating in sports by discussing concussion risks and policies with the coach and athletic staff and ensuring the team has concussion education and a concussion assessment protocol in place. Furthermore, proper use of well-maintained protective equipment and consistent enforcement of the rules by officials are all important considerations. Different families and athletes may also consider focusing on sports with lower known risks for concussions in the context of the benefits of participating in specific sports.

data is based on laboratory testing, rather than actual clinical studies that assess for reduced risk for concussion in real-world scenarios. However, helmets do protect against skull fractures and more severe TBI such as intracranial bleeds. Thus, well-maintained and properly fitted helmets should be worn in the appropriate sports. Mouthguards do prevent against dental injuries and should be worn for this reason, but no particular mouthguard can be recommended as "concussion-proof." Despite heavy mar-

keting, no convincing data exist that headbands or caps reduce rates of concussion for sports such as soccer.³

Sport-Specific Factors

Many studies have examined whether greater risk exists in playing a particular position on a team, and data for position-related differences in concussion risk are limited, particularly when looking at youth sports. However, some general considerations are worth discussing with families. Youth sports

KEY POINTS

- Collision and contact sport programs with no concussion policy and no availability of certified athletic trainers at practices and events will be less likely to consistently recognize suspected concussions and properly manage them.
- For pediatric care providers, it is important to recognize that self-reporting of symptoms of concussion can be limited for many reasons.
- If an athlete demonstrates signs or symptoms of concussion after a “hit” or collision and a concussion is suspected, that athlete should be removed from play for further evaluation and, in particular, to protect him or her from the increased risk of sustaining a repeat or more severe brain injury.

programs have a range of supervision, access to certified athletic trainers, quality of equipment, rules enforcement, and thoroughness of concussion information and regulation. Thus, parents should be encouraged to investigate the level of adult supervision, rules enforcement, and medical training available in youth sports programs in which their children participate. Collision and contact sport programs with no concussion policy and no availability of certified athletic trainers at practices and events will be less likely to consistently recognize suspected concussions and properly manage them.

In youth ice hockey, the introduction of body checking at the pee-wee level (11 to 12 years) has been associated with an increased risk and severity for concussions.^{18,22} In Canadian youth leagues, these findings have led to rule changes to eliminate body checking at the youngest ages; however, similar rule changes are not widespread for youth ice hockey in other nations.

The majority of youth sports studies were of high school level athletes. For a summary of risk factors that have been described in studies of youth athletes see **Table 3-1**.

ACUTE PRESENTATION AND ASSESSMENT

Symptoms and Signs

The signs and symptoms for concussion are outlined in **Table 3-2**. For pediatric care providers, it is important to recognize that self-reporting of symptoms can be limited for many reasons. In older teens and young adults, symptoms are often underreported in an effort to evoke a sense of toughness, to demonstrate dedication to the team, to not relinquish a position on the team, or sometimes simply because of lack of knowledge.^{23,24} Younger teens and children may report symptoms using simpler vocabulary and may be more suggestible to leading questions or to parental influences. In any case, if an athlete demonstrates signs or symptoms of concussion after a “hit” or collision and a concussion is suspected, that athlete should be removed from play for further evaluation and, in particular, to protect him or her from the increased risk of sustaining a repeat or more severe brain injury.

Diagnostic Tools

One of the more widely used tools is the Sport Concussion Assessment Tool

TABLE 3-1 Risk Factors for Concussion^{a,b}

- ▶ Female > male (for comparable sports such as soccer, basketball, baseball/softball)^c
- ▶ Higher level of sport (college > high school)^c
- ▶ Competition > practice^c
- ▶ In boys, highest-risk sports include football, ice hockey, and lacrosse, followed by soccer, wrestling, and basketball^c
- ▶ In girls, highest-risk sports are soccer, ice hockey, and lacrosse, followed by basketball, field hockey, softball, and gymnastics^c
- ▶ History of prior concussion^c
- ▶ Body checking in pee-wee hockey^c

^a No conclusive evidence that a particular helmet, mouthguard, or headband/cap reduces concussion rates.

^b No conclusive evidence of higher risk with a particular position in a given sport.

^c Risk factors for which existing evidence includes at least one study involving athletes of high school age or younger.

(SCAT). The most recent version of the SCAT was updated in 2013 and is called the SCAT3.⁴ The SCAT incorporates several validated components, including a graded symptom checklist, a cognitive assessment (Standardized Assessment of Concussion [SAC]), a balance measure (Balance Error Scoring System [BESS]), and Maddocks questions. The Maddocks questions are a series of sports-relevant orientation questions that include asking the following: (1) Where are we playing today?; (2) Which half/period is it now?; (3) Who scored last in this game/match?; (4) What team did you play last week/game?; (5) Did your team win the last game? As with most concussion tools, these questions have not specifically been tested in pediatric populations. Initial assessment for concussion may take place on the field or sideline. Many concussion assessment tools exist, but only the Maddocks questions are validated for on-field assessment and can be conducted in a time frame available. Clinical findings suspicious for concussion would include reporting any symptoms commonly associated with a concussion, having difficulty answering the Maddocks questions, or demonstrating slowed responses or incoordination (Case 3-2).

Other concussion assessment tools may be utilized, preferably by a practitioner experienced in their use and in a controlled environment (ie, in the locker room as opposed to on the sideline). These include part or all of the SCAT3, such as the graded symptom checklist, SAC, and BESS. Computerized or paper-and-pencil neuropsychological testing is generally not practiced nor indicated in the acute setting.

In the proper setting, these components have good sensitivity and specificity for suspecting or diagnosing concussion. However, systematic study of these tools in pre-high school-age individuals has not been conducted.

TABLE 3-2 Common Signs and Symptoms of Concussion

► **Early**

Headache
Dizziness
Nausea and vomiting
Light and noise sensitivity
Vacant stare (looks “out of it”)
Slow to talk or do things
Confusion and inattention
Disorientation
Slurred or incoherent speech
Loss of coordination
Emotions out of proportion to circumstances
Memory loss (amnesia)
Any period of unconsciousness

► **Late**

Headache
Dizziness
Light and noise sensitivity
Nausea
Slow to talk or do things
Loss of coordination
Emotions out of proportion to circumstances
Inattention
Memory problems
Depression
Anxiety
Sleep disturbance

Given some of the potential challenges of having children aged 5 to 12 years respond consistently to queries about symptoms and cognitive testing, the Zurich Consensus Guidelines made a recommendation for a modified version of the SCAT3 called the Child-SCAT3. The 22-item graded symptom checklist from the SCAT3 has been revised to a 20-item symptom checklist with simpler

KEY POINTS

- While there is an increasing push to obtain baseline testing, evidence of its utility for interpretation of concussion diagnostic tests has been mixed.
- When interpreting or conducting baseline testing (whether computerized and noncomputerized tests or clinically administered Sport Concussion Assessment Tool 3), the practitioner should be aware of nonconcussion reasons for poor or invalid scores.

Case 3-2

A 14-year-old girl was playing soccer and collided with another player, falling and striking the side of her head. She lay on the field, apparently with the wind knocked out of her. The sideline doctor with the team ran onto the field and began his assessment. Airway, breathing, circulation, and cervical spine appeared to be okay. A sideline evaluation for concussion was conducted, including Maddocks questions and a brief screening for concussion-related symptoms and assessment for neurologic/balance impairment. After a brief assessment, a concussion was suspected, and she was removed from play until a more thorough evaluation could be completed.

Comment. On the sideline or at the game, it is not necessary to diagnose a concussion, only to suspect it. If suspected, the athlete should be removed from play that day. For the most part, formal diagnosis of concussion would occur in either the clinic, urgent care facility, or emergency department setting, although in some settings in higher levels of sport experienced athletic trainers or team physicians may be able to conduct a proper evaluation at the sporting venue.

vocabulary in the Child-SCAT3. In addition, the Child-SCAT3 symptom checklist includes a parental symptom questionnaire that covers the same questions but asks the parents to independently rate the child's symptoms.

Furthermore, the cognitive testing portion (SAC) has simplified attention testing in the child version, using shorter digit spans than the adult version and asking for the child to recite the days of the week backward (instead of the months of the year). While these pediatric modifications make sense, the modified tool has yet to be validated, although studies are under way.

Neurocognitive testing has also been used in the assessment of sports-related concussion. Both computerized and standardized paper-and-pencil testing can be used, but require age-matched normative data or baseline data for comparison. Differences in the types of computerized testing that may be relevant when considering their use in younger children include duration of testing, complexity of instructions, and how gamelike or entertaining the testing is.

Other measures used to assess for sports-related concussion in older patients include clinical reaction time²⁵

and the King-Devick test.²⁶ These have had only limited use in younger children and await age-matched normative data before ascertaining their utility.

Baseline Testing

While there is an increasing push to obtain baseline testing, evidence of its utility for interpretation of concussion diagnostic tests has been mixed. When interpreting or conducting baseline testing (whether computerized and noncomputerized tests or clinically administered SCAT3), the practitioner should be aware of nonconcussion reasons for poor or invalid scores, which include, but are not limited to: poor attention, not understanding instructions, "sandbagging" (purposely performing poorly on the test), pre-existing neurocognitive problems, poor motivation/boredom, fatigue/exhaustion, dehydration, micturition urgency, and many other possible factors. Unlike post-concussion testing, which is properly conducted individually and in as quiet a setting as possible, baseline testing is often done in larger groups, with more noise and distraction and frequently after class or practice. The pediatric practitioner will recognize almost immediately

that any of these pitfalls for baseline testing can be exacerbated in younger athletes; for example, attention spans are shorter, children are easily bored if baseline testing is prolonged, they may be tired or unmotivated at the end of a school day or practice, more complex instructions may be misunderstood, and younger children may respond in a manner they perceive will please the questioner/adult.

If baseline testing is conducted, it should be conducted in as quiet and nondistracting an environment as possible, ideally, individual rooms or at least with the testing area separate from the waiting area. For baseline computer testing, studies suggest that younger age and larger groups are less optimal and have a higher rate of invalid results.²⁷ Before using baseline tests conducted by others, be sure to have an understanding about how the tests were carried out to determine whether the data are reliable.

The take-home message about using concussion diagnostic tools and baseline testing is to recognize that no single test exists that will accurately diagnose concussion and to be aware of the limitations of these tests in younger teens and children. For the experienced practitioner, these concussion diagnostic tests simply represent additional tools to help with a complex diagnosis, but the final diagnosis of concussion still rests with a careful neurologic history, physical examination, and neurologic/cognitive examination.

Second Impact Syndrome

Second impact syndrome is clinically described as malignant cerebral edema and neurologic collapse after sustaining two or more concussive blows with incomplete recovery between them.²⁸ Cases described in the literature typically lapse rapidly into a coma, may have physical or imaging signs of increased

intracranial pressure and cerebral edema, require intensive care unit care, and have high rates of mortality.

However, careful review of reported cases finds that the element of repetitive injury is often poorly documented.^{29,30} Sports with frequent repetitive concussive blows, such as amateur boxing and football, actually report such cases only very rarely. It has been suggested that, rather than second impact syndrome, these cases be referred to as diffuse cerebral swelling after mild TBI. These cases have a propensity for younger persons, with most reported cases occurring under the age of 20 years. Interestingly, in a family pedigree of patients with *CACNA1A* mutations and familial hemiplegic migraine, multiple members experienced cerebral edema and severe alteration of mental status after mild TBI.³¹ As the pathophysiology of concussive injury involves indiscriminate ionic flux of Na⁺, K⁺, and Ca⁺⁺,³² it is interesting to speculate that diffuse cerebral swelling occurs in some genetically susceptible young persons after concussion, and that this susceptibility may relate to ion channelopathies. However, this idea remains to be proven.

Acute Imaging: CT

CT scanning to identify fractures or hemorrhage after mild TBI often occurs, but the likelihood of CT detecting a clinically important intracranial complication after mild TBI is extremely small. Existing evidence suggests that CT has little advantage over simple observation in determining the small percentage of patients who go on to require hospital admission, mechanical ventilation, or neurosurgery, or whose injuries result in death. While studies looking specifically at youth sports-related concussion are limited, a very large cohort of pediatric mild TBI cases presenting to emergency departments has been investigated.⁵ A

KEY POINTS

- No single test exists that will accurately diagnose concussion, and it is important for the practitioner to be aware of limitations of these tests in younger teens and children.
- For the experienced practitioner, concussion diagnostic tests simply represent additional tools to help with a complex diagnosis, but the final diagnosis of concussion still rests with a careful neurologic history, physical examination, and neurologic/cognitive examination.

FIGURE 3-1 Indications for CT scanning for mild traumatic brain injury in patients older than 2 years.

ciTBI = clinically important traumatic brain injury; CT = computed tomography.

^a Clinically important traumatic brain injury (TBI) includes death due to TBI, TBI that requires neurosurgical intervention, intubation of more than 24 hours for TBI, and hospital admission of two or more nights for TBI.

^b Severe mechanism of injury (eg, motor vehicle accident with ejection, death of another passenger, or rollover; pedestrian or cyclist without helmet struck by motor vehicle; fall of more than 1.5 meters; or head struck by high-impact object) is rare for sports-related TBI.

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KEY POINTS

- The majority of pediatric mild traumatic brain injury/concussion patients presenting to the emergency department may be carefully observed and do not require CT scanning.
- Any child suspected of concussion should be removed from contact risk at that time and not be returned the same day.

clinical rule on which patients not to scan has been derived and validated in two separate cohorts of patients. This rule (for pediatric patients older than 2 years) is shown in **Figure 3-1**. Based on this algorithm, the majority of pediatric mild TBI patients presenting to the emergency department may be carefully observed and not undergo CT scanning. The optimal duration and setting of observation still remains to be determined.³³

EARLY CONCUSSION MANAGEMENT Removal From Play

The strongest evidence for management after suspected concussion is removal

from play with no return until assessed by an experienced physician, familiar with both concussions and more severe TBI. It is known that the risk for repeat concussion is greatest within 7 to 10 days after concussion,^{20,34} which corresponds to a window of metabolic and ionic vulnerability described in experimental studies.³² During this initial time window, the concussed athlete may also have impaired attention, balance, reaction time, or higher cognitive processing, all of which may conspire to make a repeat injury more likely. Any child suspected of concussion should be removed from contact risk at that time and not be returned the same day.

Pediatric practitioners should be aware that risks for repeat concussion include the reversible factors listed above, which generally are expected to diminish as the patient recovers over time in the vast majority of cases. However, some potential risk factors for repeat concussion may contribute to a longer-term risk. These include preexisting conditions such as inattention, impulsivity, or hyperactivity; possible genetic factors; poor neck strength; and certain playing styles such as head-down tackling. Some of these factors may be mitigated through proper neurobehavioral treatment (inattention/hyperactivity), improved conditioning (neck strength), or coaching (poor playing habits).

Evaluating Risk Factors for Prolonged Recovery

Studies suggest that high school athletes generally take longer to recover from concussions than collegiate or professional athletes.^{13,14} While most individuals with concussions recover to baseline within 10 to 14 days, a notable proportion (5% to 20%) may have persisting symptoms or cognitive deficits that last longer.³⁵ When initially evaluating the patient, the practitioner should

take into account the athlete's past medical history and current symptomatology to identify the presence (or absence) of known risk factors for prolonged recovery. These risk factors are listed in **Table 3-3**, indicating those identified in studies that included pediatric patients (less than 18 years of age). Part of the individualized management of concussions involves developing a rough time frame of anticipated recovery.

Anticipatory Guidance and Cognitive Restructuring

Multiple studies, including pediatric studies, have suggested that reassurance, education about the injury, and brief psychological counseling in the early phases can reduce the risk for later development of postconcussion syndrome.³⁶ Anticipatory guidance, a term common in general pediatrics, is appropriate in such a situation. The patient and family should be informed that a concussion is a type of recoverable brain injury, whether the individual's symptoms are typical or not, and an approximate time frame of expected recovery should be provided based on

the clinician's assessment of the individual youth. Verbal education should be combined with written or electronic sources of accurate information, and both parents' and the child's questions should be answered candidly.

Cognitive Rest

Growing evidence suggests that a brief period of cognitive rest may be implemented to help facilitate recovery in the acute phase. Several studies suggest that a period of reduced cognitive effort or activity may be associated with fewer symptoms and more rapid recovery.³⁷⁻³⁹ Cognitive rest does not have a uniform definition, but in general it is referred to as avoiding cognitive tasks that clearly exacerbate symptoms, particularly in the first few days after a concussion. It should be noted that severe and prolonged restriction of activities, referred to as cocoon therapy, may have deleterious consequences, such as development of anxiety and depression, and that moderate levels of activity while avoiding these potential complications may benefit the patient.^{37,38}

KEY POINTS

- Multiple studies, including pediatric studies, have suggested that reassurance, education about the injury, and brief psychological counseling in the early phases can reduce the risk for later development of postconcussion syndrome.
- Several studies suggest that a period of reduced cognitive effort or activity may be associated with fewer symptoms and more rapid recovery from concussion.

TABLE 3-3 Risk Factors for Prolonged Recovery^a

Risk Factor Evidence	Number of Studies and Level of Evidence
History of prior concussion	4 Class I, 2 Class III
Younger age	2 Class I
Headache	1 Class I, 5 Class II
Fogginess	1 Class I, 2 Class II
On-field loss of consciousness, posttraumatic amnesia, >5 minute alteration in mental status	1 Class I, 1 Class II, 2 Class III
History of prior headaches	1 Class II
History of prior learning disability or cognitive/attentional problems	1 Class II
Dizziness	1 Class III

^a Risk factors for which existing evidence includes at least one study involving athletes of high school age or younger, except for a history of prior learning disability or cognitive/attentional problems.

KEY POINTS

- Concussion management should be individualized, taking into account risk factors for prolonged recovery, offering anticipatory guidance, moderating (but not stopping) cognitive activity, and providing symptom-based supportive care.
- Sleep disturbances are commonly reported early after a concussion, and counseling regarding good sleep hygiene can be very helpful in the early stages after a concussion; poor sleep hygiene in the early phases has the potential to prolong recovery.

Supportive Care

In the acute phase, athletes and families should be reassured if their symptoms are typical for concussion and monitored for gradual improvement (realizing there will be some ups and downs). In cases of severe acute headaches, pharmacologic management with over-the-counter analgesics may be needed. The family should be informed about the possibility of developing medication overuse/rebound headaches and counseled appropriately. Strong narcotics should be avoided. A healthy diet and good nutrition should be reinforced during the acute phase, including adequate hydration and avoiding skipping meals. Sleep disturbances are commonly reported early after a concussion, and counseling regarding good sleep hygiene can be very helpful in the early stages after a concussion; poor sleep hygiene in the early phases has the potential to prolong recovery.

RETURN TO LEARN AND RETURN TO PLAY**Return to Learn**

In the acute phase after a concussion, individualized cognitive rest should be

considered, as described above. Extremes of activity should be avoided, as well as activities that clearly worsen symptoms for that particular individual. In the school-age student athlete, return to learn is a critical consideration, and prolonged absences from school should be discouraged. Based on symptoms and cognitive testing, some students will require at least temporary academic accommodations, and this plan should be worked out with the school, including frequent reassessment of the student's progress. Commonly used academic accommodations are summarized in **Table 3-4**,⁴⁰ and forms such as the Acute Concussion Evaluation (ACE) may be helpful for practitioners to provide written instructions for the family and school.⁴¹ Return to learn should precede return to play, and several consensus statements support this assertion.^{2,42}

Return to Play

Return to play is currently managed predominantly by a stepwise consensus-based progression of physical activity outlined in **Table 3-5**.⁴ Step 1 involves the acute phase, where athletes are restricted from any major physical

TABLE 3-4 Common Options for Temporary Academic Accommodations After Concussions^a

- ▶ Shortened day
- ▶ Shortened classes (ie, rest breaks during classes)
- ▶ Allow extra time to complete coursework/assignments and tests
- ▶ Lessen homework load
- ▶ No significant classroom or standardized testing at this time
- ▶ Check for the return of symptoms when doing activities that require a lot of attention or concentration
- ▶ Take rest breaks during the day as needed
- ▶ Request meeting of teachers or school management team to develop individualized plan and needed supports

^a Data from Gioia G, Collins M.⁴⁰ www.cdc.gov/concussion/headsup/pdf/ace_care_plan_school_version_a.pdf.

TABLE 3-5 Steps of the Graduated Exertion Process^{a,b}

Step ^c	Notes
1. Light aerobic exercise	Stationary bike
2. Sport-specific aerobic exercise	Add movement and balance
3. Noncontact training drills	Add cognition and agility
4. Contact training drills	After medical clearance
5. Return to play	Full game play

^a Modified with permission from McCrory P, et al, Br J Sports Med.⁴ © 2013, BMJ Publishing Group Ltd and the British Association of Sport and Exercise Medicine. bjsm.bmj.com/content/47/5/250.full.

^b To be initiated when the patient is no longer experiencing concussion-related signs or symptoms with routine activities of daily living.

^c Proceed to next step only after enough time has passed to clinically determine the absence of sign or symptom recrudescence.

KEY POINT

■ Return to learn should occur in a gradual fashion, limited by symptom exacerbation, and should precede return to sport. The gradual return-to-play protocol should begin after resolution of acute symptoms in individuals not taking symptom-masking medications.

activity while symptomatic or while taking medications aimed at reducing symptoms. Upon resolution of acute symptoms and discontinuance of symptomatic medications, the child may then be advanced to step 2. This is similar to the gradual return-to-play protocol used at all levels of sports; however, given the evidence for longer concussion recovery time in high school (and possibly younger) athletes, instead of 24 hours

at each step, pediatric athletes may be managed using 24 to 48 hours at each step.^{1,4} It is important to distinguish between return to physical activity (steps 2, 3, and possibly 4) and return to contact risk (possibly step 4 and definitely steps 5 and 6) (Case 3-3).

Some evidence exists to support controlled, low-level physical activity to facilitate recovery in patients with chronic symptoms.⁴³ For patients with chronic

Case 3-3

A 17-year-old boy presented to the clinic 9 days after a concussion sustained during a hockey game in order to be evaluated for his readiness to return to play. On examination, the patient reported resolution of his postconcussion symptoms and expressed eagerness to return to play. Clinical evaluation included a normal neurologic examination, including eye movements, cerebellar testing, and balance testing. The patient had undergone a baseline computerized cognitive test, and when this test was repeated in the clinic, the results demonstrated that he was at his baseline cognitive performance. He had been back in school for about 1 week and performing at his prior academic level. He was cleared to step 2 in the gradual return-to-play progression (Table 3-5), which includes gentle aerobic exercise. This was supervised and started with 10 to 15 minutes on a stationary cycle at less than maximal effort. At each stage, he was then monitored for return of concussion symptoms. Over the next 5 days, he advanced from light aerobic (step 2) to aerobic with movement (step 3), and then to noncontact sports activity and weightlifting (step 4). The evening after his step 4 workout, he reported to his parents some headache, "fogginess," and feeling a little unsteady. The following day his workout was reduced to the last regimen that did not exacerbate his symptoms (step 3).

Continued on page 1580

KEY POINT

- Treatable sequelae of concussions include posttraumatic headaches and behavioral problems such as depression and anxiety.

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Comment. Evidence suggests that return-to-contact risk while still symptomatic or showing evidence of neurocognitive dysfunction may predispose to a repeat concussion. No set time scale exists for return to play for all athletes, but each return to play should be individualized based upon risk factors and ongoing signs/symptoms. Consensus recommendations indicate that once acute symptoms have resolved, an athlete should enter a gradual return-to-play protocol in which he or she is carefully monitored for return of symptoms at each level.

symptoms not exacerbated by low-level physical activity, allowing some non-contact-risk exercise may be beneficial. Basic neuroscience work also supports the concept that enhancing neural activity outside of the acute injury period may facilitate expression of neurotrophins and promote better cognitive recovery.^{44,45}

CHRONIC POSTCONCUSSION SEQUELAE

Following a concussion, the vast majority (90% to 95%) of high school football players recover within 3 to 4 weeks.³⁵ However, a small subset develop persistent symptoms, including headache and cognitive or behavioral problems. This subset can be challenging and will often return for further medical intervention.

Posttraumatic Headaches

After a concussion, headache is the most common acute symptom (90%). However, it is also quite common as a chronic sequela after TBI in children.⁴⁶ While the approach to the acute headache is mostly related to symptom relief and allowing the concussion to heal with time, chronic postconcussion headaches may warrant additional diagnostic testing (including imaging if clinically indicated) and often specific pharmacologic management. No randomized trials of medication for postconcussion headache in children or adults exist, so the approach to chronic postconcussion headaches is much like the approach to chronic daily headaches or chronic migraine.^{47–49}

Concussion may trigger or exacerbate migraines, and the underlying pathophysiology of concussion involves an ionic flux resembling spreading depression, similar to that known to occur in migraine.³² For persistent, frequent postconcussion headaches with migraine symptomatology, the approach is to look for additional triggers or exacerbating factors, use prophylactic medications, and maintain a headache log to monitor for treatment response. Good diet, hydration, and sleep hygiene should all be emphasized, and noncontact, light aerobic exercise may play a role.

Prophylactic pharmacotherapy can be selected much as one might treat migraine, with choice of medication based upon comorbidities and potential for side effects. Amitriptyline or other tricyclic antidepressants are useful and may be titrated upward in cases with chronic postconcussion migraines. Sedating side effects and antidepressant effects may be beneficial in patients with sleep disturbance or depressive symptoms, respectively, although the initial doses used for headache prophylaxis are generally lower than mood-stabilizing doses. Certain anticonvulsants may also be helpful for chronic headaches; however, care should be taken because of the potential for cognitive side effects, particularly with topiramate. Butterbur (*petasites*) has good evidence for efficacy in migraine prevention, although has not specifically

been studied in children with or without concussion. Other possible treatments include riboflavin, magnesium, beta-blockers, and calcium channel blockers.

For patients with clear episodic migraine attacks, abortive migraine agents may be used just as one would treat nontraumatic migraine. Obvious headache triggers should be avoided as much as possible. It is reasonable to make the record-keeping for the headache log as simple as possible since frequent querying by the parents about the child's headaches is likely to trigger anxiety and may contribute to worsening symptoms. It should be recognized that prior migraines may be a risk factor for persistent postconcussion migraine headaches. Also, it is important to recognize the variants of migraine that may occur more often in children, including confusional migraine and basilar migraine, which present with ominous symptoms (such as alteration in mental state, vertigo, ataxia, and cranial nerve deficits) and may trigger extensive emergent evaluation. Lastly, other etiologies of chronic headache should be considered, such as medication overuse, tension or cervicogenic headaches, and appropriate interventions should be instituted in these cases.

Depression and Anxiety

The most common behavioral problems after concussion include depression and anxiety. A recent study found that a prior history of concussion was associated with a threefold risk of depression in an adolescent cohort.⁵⁰ Whether these are new diagnoses after concussion versus an exacerbation of an underlying predisposition or premorbid condition is not clearly known. Studies of pediatric mild TBI that include an orthopedically injured control group have suggested that much of the chronic symptomatology and neurocognitive impairment is related to premorbid behavioral and environmental

conditions.^{51,52} In any case, a major goal is to return the child to as normal a social and school environment as possible after concussion. Should chronic behavioral issues be noted, referral to child psychiatry or psychology may be warranted.

Chronic Neurocognitive Impairment Versus Chronic Traumatic Encephalopathy

Tremendous concern exists in the lay public and medical providers about neurodegeneration induced by repetitive concussions, termed chronic traumatic encephalopathy (CTE), based on case series of cerebral tau deposition seen at autopsy in contact and collision athletes. Some of these cases were young persons, and the youngest case was a teenager.¹¹ Given the nature of these reports, however, it is not possible to ascertain the incidence or prevalence of CTE. While some clinical characteristics have been reported in an effort to aid premortem diagnosis, the common clinical signs and symptoms are not particularly specific.⁵³

Despite the controversy surrounding the diagnosis of CTE, many studies have looked at chronic neurocognitive impairment in contact and collision sport athletes.^{1,2} In these studies, chronic neurocognitive impairment is determined by the use of formal neuropsychological testing, but without a longitudinal component that would permit diagnosis of a neurodegenerative disorder. A common theme of these studies is that professional athletes in many contact and collision sports show lower scores on neuropsychological testing when compared with non-contact athletes, and that the degree of this chronic neurocognitive impairment is dose-dependent on their exposure to the sport, whether measured by number of reported concussions, years of play, or other sport-specific variables (eg, number of fights in boxing or number of headers

KEY POINT

■ It is likely that repeated concussions contribute to chronic neurocognitive impairments later in life; however, the true incidence of neurodegenerative disorders such as chronic traumatic encephalopathy is unknown.

in soccer). These are largely Class I or Class II studies and have been conducted in professional football, rugby, boxing, soccer, and horseracing.⁵⁴⁻⁵⁷

Despite this concerning evidence, even more studies looking at chronic neurocognitive impairment have been conducted in amateur athletes (high school, college, and adults). Unlike the dose-response relationships reported in professional sports, the results of these studies are inconsistent, with an almost equal numbers of studies showing measurable impairments on neuropsychological testing and studies showing no impairment. Furthermore, there is a paucity of data looking at chronic neurocognitive impairment after concussions sustained in patients younger than high school age.

These data do not imply that no risk exists for chronic problems after youth concussions; they do suggest that the risk of long-term cognitive sequelae after mild TBI/concussion in children

is uncertain, and the relationship between repeated concussions and chronic neurocognitive impairment appears less consistent than the data obtained in professional contact and collision sport athletes.

CONCLUSION

Assessment and management of sports-related concussions is challenging, even more so in the pediatric population where developmental differences and a relative lack of strong evidence make a one-size-fits-all approach outdated and unhelpful. At the same time, the number of participants in youth sports vastly outnumbers the higher-profile athletes at the collegiate or professional levels. It is increasingly recognized that repeated concussions in youth sports are a major public health concern and that additional research should focus on this area.¹⁻⁴ A proposed approach to the assessment and management of youth concussions is offered in **Figure 3-2**.

For the neurologist caring for young athletes, there are several take-home messages. First, no single test exists to diagnose concussion in any population, and most of the tests used have limited validation data in younger patients. It is important for the clinical care provider to be familiar with the different tools, to realize their limitations, and to remember that the neurologic history and examination are also critical in diagnosing concussions in children and adolescents. Second, the use of acute CT imaging for youth concussions is not routinely recommended. Third, no single management plan or time frame for recovery after concussion exists, and this must be individualized based upon risk factors and current symptoms. Reassurance and education about concussions and assistance with managing postconcussion activity are proven to help reduce the likelihood of developing chronic persistent symptoms. Fourth, reasonable evidence exists that high school and younger athletes take longer to recover and thus may warrant a more conservative return to activity protocol. Lastly, for youths recovering from concussion, return to learn is a higher priority than return to play, and a gradual plan that involves initial cognitive rest but also avoids prolonged absence from school and social environments may offer the best opportunity for timely recovery and optimal outcomes.

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