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Pediatric Sport-Related Concussion: A Review of the Clinical Management of an Oft-Neglected Population

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ABSTRACT

Athletic concussion is a growing focus of attention for pediatricians. Although numerous literature reviews and clinical guidelines are now available pertaining to athletic concussion, few have focused on the pediatric athlete in particular. Sport-related concussions occur relatively frequently in children and adolescents, and primary health care providers are often responsible for coordinating clinical management. Here we summarize the scientific literature pertinent to the care of young athletes. We examine how concussion affects younger and older athletes differently at biomechanical, pathophysiological, neurobehavioral, and contextual levels. We also discuss important issues in clinical management, including preparticipation assessment, concussion evaluation and recovery tracking, and when and how to return pediatric athletes to play sports. We also briefly cover non-sport-related interventions (eg, school support). With proper management, most children and adolescents sustaining a sport-related concussion can be expected to recover fully.

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Key Words

concussion, mild traumatic brain injury, athletic injuries

Abbreviations

TBI—traumatic brain injury
mTBI—mild traumatic brain injury
PCS—postconcussive symptoms
CISG—Concussion in Sport Group
CSI—Concussion Symptom Inventory

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OVER THE LAST 2 decades, sport-related concussion has received an increasing amount of popular and scientific attention. Because the athletic and financial stakes at the college and professional levels are incredibly high, the bulk of this attention has focused on the older competitive athlete. The sheer number of participants in youth and high school sports, however, makes the identification and management of pediatric sport-related concussion of major public health import. Nearly 60% of high school students in the United States participate in organized sports, with numbers growing annually and many more involved in the younger years.¹⁻³ In gridiron football alone, 1.5 million athletes participate at the high school and more junior levels.⁴

DEFINITION AND EPIDEMIOLOGY

A concussion is a type of mild traumatic brain injury (mTBI) that is caused by an impact or jolt to the head. The American Academy of Neurology straightforwardly defines concussion as a “trauma-induced alteration in mental status that may or may not involve a loss of consciousness.”⁵

Each year >300 000 sport-related mild-to-moderate TBIs occur in the United States.⁶ Nearly all athletic endeavors pose some risk of concussive injury. Among the more commonly played high school sports, football and ice hockey have the highest incidence of concussion, followed by soccer, wrestling, basketball, field hockey, baseball, softball, and volleyball.^{7,8} In certain sports (eg, football, rugby), the risk of injury depends on the position played.^{8,9} Higher rates of concussion are seen in games than practices, excepting possibly volleyball and cheerleading.^{8,10} Solid concussion incidence data do not yet exist for pre-high school populations.

CONCUSSION EFFECTS

Clinically, immediate signs and symptoms of a sport-related concussion are similar in younger and older athletes and can include a change in playing ability, a vacant stare, fogginess, confusion, slowing, memory disturbance, loss of consciousness, increased emotionality, incoordination, headache, dizziness, and vomiting. Most children and teenagers recover fully from a single, uncomplicated mTBI.¹¹⁻¹⁵ However, recovery takes time, and in the days, weeks, and even months after injury, a number of neurobehavioral problems can be seen, not unlike those commonly reported in adults.¹⁶ These postconcussive symptoms (PCS) are often heuristically divided into 3 general domains and can include any combination of the following problems:

1. Somatic: headaches, fatigue and low energy, sleep disturbance, nausea, vision changes, tinnitus, dizziness, balance problems, sensitivity to light/noise

2. Emotional/behavioral: lowered frustration tolerance, irritability, increased emotionality, depression, anxiety, clinginess, personality changes
3. Cognitive: slowed thinking or response speed, mental fogginess, poor concentration, distractibility, trouble with learning and memory, disorganization, problem-solving difficulties

CONCUSSION IN THE YOUNG VERSUS OLDER ATHLETE

Concussions in the pediatric and adult athlete differ. Children are not “little adults.” They are actively developing organisms who respond differently, have different needs, and face different expectations after injury. An appreciation of these differences and their implications is crucial for providing optimal care to the young athlete after concussion.

Biomechanical Properties

The general biomechanics of concussion are complex but have been fairly well established for some time.¹⁷⁻¹⁹ More recently, sophisticated data from real-time accelerometers, video analysis, and dummy reconstruction models have been used to examine the biomechanics of sport-related concussion in particular.²⁰⁻³⁰ Across age groups, commonalities are apparent in the physical dynamics, because all concussions primarily involve rotational acceleration and/or deceleration forces that stress or strain the brain tissue, vasculature, and other neural elements.^{31,32}

Because the compositional and mechanical properties of the head and brain differ between developing and mature organisms, the specific effects of the applied forces will be age-dependent to a certain extent. Developmental factors such as brain water content, cerebral blood volume, level of myelination, skull geometry, and suture elasticity undoubtedly affect the biomechanics of concussive injury, although exactly how remains largely undetermined.³³⁻³⁶

Developmental properties of brains and skulls may also specifically influence the threshold necessary to produce injury.³⁷ Experimental data suggest that the smaller size of immature brains could require increased force to produce actual cerebral injury,³⁸ an idea supported by a recent study finding that skull fracture is associated with greater risk of intracranial injury in adults than children.³⁹ Hence, as McCrory et al⁴⁰ highlight, young children may require increased force when compared with adults to become symptomatic after head injury, although physiologic and neurobehavioral data reviewed in the next sections suggest that once actual injury occurs, the immature brain is likely to respond less well overall.

The immature musculoskeletal systems that characterize young athletes can also be expected to influence injury dynamics. For a concussion to occur, mechanical

energy not only needs to be of sufficient mass and acceleration, it also needs to be absorbed directly by the head.⁴¹ Because children have less well-developed neck and shoulder musculature than adults, they will not be as able to transfer energy directed at the head throughout the body, increasing their risk of concussive injury in certain circumstances. On the other hand, given younger athletes' diminished size and strength, lower force/mass ratios will characterize their collisions, leading to decreased injury rates in most situations.^{42,43}

Pathophysiological Response

The brain's pathophysiological response to concussion has been described in detail by using animal models.^{44,45} Changes after concussion include abrupt neuronal depolarization, release of excitatory neurotransmitters, ionic shifts, altered glucose metabolism and cerebral blood flow, and impaired axonal function. Research on more severe brain injury suggests that this pathophysiological cascade is likely to differ in the developing organism. The incidence of brain swelling and cerebral edema after moderate-to-severe brain injuries, for example, is higher in children than in adults.⁴⁶

Clinical evidence also suggests that physiologic responses are age-dependent after mTBI. Most prominently, age-based differences are seen in "second-impact syndrome," which, as commonly described, results from a second blow to the head while a youth is still symptomatic from a previous concussion.^{47,48} Disruption to autoregulation of the brain's blood supply is thought to underlie second-impact syndrome, the symptoms of which may include vascular engorgement, diffuse cerebral swelling, increased intracranial pressure, brain herniation, and ultimately coma and death.⁴⁹ Although controversy continues about whether the second impact actually plays a role in triggering the neurologic consequences,^{50,51} agreement exists that diffuse cerebral swelling or malignant cerebral edema does occur in very rare cases after mTBI and that immaturity of the brain is a clear risk factor.⁵²⁻⁵⁵

Neurobehavioral Outcome

Traditionally, young age at the time of brain injury has been thought to have protective benefits; the "Kennard principle" holds that the young brain's plasticity would allow for more recovery after insult.⁵⁶ However, a growing literature, including studies of more severe TBI, strongly indicates that the immature brain is more vulnerable, not more plastic, to diffuse injury.⁵⁷⁻⁶⁷ Several hypotheses have been put forth to help explain this increased vulnerability: skills not yet well established at the time of insult could be more susceptible to disruption than well-established ones; the brain systems responsible for skill acquisition could be affected directly by diffuse injury; functional recovery may be restricted by the injured child's smaller repertoire of existing skills;

and an injury to the immature brain could interfere neurobiologically with the intricate sequence of chemical and anatomic events necessary for normal development.^{44,68-70}

Initial studies of sport-related concussion have indeed suggested that recovery may be less positive in younger athletes, at least from a cognitive perspective. Field et al⁷¹ compared recovery after concussion in high school and college football and soccer players. Despite the higher incidence of premorbid concussions among the college athletes, high school athletes displayed more protracted recovery rates as measured by neuropsychological testing.

Contextual Expectations

The contextual or environmental demands faced by children and adults differ as well. Adults have already learned and mastered much of the knowledge and many of the skills they need to function successfully in everyday settings. In contrast, children are continually expected to acquire new information and skills, especially during the school months. Thus, they are often expected to use a set of neurobehavioral skills that are vulnerable to mTBI, such as the ability to focus and sustain attention, rapidly process information, and hold information in mind while generating a response.^{16,72,73} As a result, clinical management of pediatric concussion requires an understanding of the contextual demands that children face across development⁷⁴ to allow for the provision of suitable assistance.

Another obvious contextual divergence between children and adults in the management of concussion is that the individuals involved in decision-making and care will differ. Children have parents or guardians who are legally responsible for their medical decisions. Moreover, contrary to the older competitive athlete, the pediatric athlete's clinical management will most often be directed by a primary care practitioner rather than a team physician. The vast majority of young athletes also attend school and thus have access to a variety of concerned professionals outside the family and sports arena who can be recruited to help ensure appropriate monitoring and support postconcussion if adequate knowledge of the educational system is available.

CLINICAL MANAGEMENT

Although most athletes will recover within the first hours, days, or weeks after a concussion, no 2 injuries will be exactly alike. Regardless of age, the specific symptom pattern will depend on innumerable injury, personal, and contextual factors (eg, severity and location of injury forces, genetic make-up, gender, learning and previous injury history, psychiatric status). Therefore, clinical care needs to be individualized and matched to the particular person and his or her own unique circumstances to ensure that medical, cognitive, emotional,

TABLE 1 Clinical Management Overview of Pediatric Sport-Related Concussion

Preparticipation medical contact
Gather relevant data
Brain injury history, including symptom-based concussion assessment
Baseline level of "postconcussive" symptomatology
Provide education
Injury prevention
Injury recognition (eg, loss of consciousness is not the only indication of a concussion)
Immediate postconcussion evaluation
Rule out medical emergencies
Thorough physical examination
Neuroimaging as indicated
Assess mental status in standardized fashion
If concussion is suspected, no return to play until medically cleared
Recovery tracking
Conduct serial physical examination
Systematically evaluate PCS
Return to play
At earliest, return athlete to play when:
No signs or symptoms of any kind are apparent at rest or during exertion
Neurologic examination is normal
Neuroimaging is unremarkable when performed
Return in gradual, stepwise fashion
Nonsport considerations
Provide general concussion education to patient, parents, and school personnel
Ensure appropriate support in place for transition back to school
Treat each medical problem symptomatically
Expect positive outcome for most children
When recovery is not proceeding as expected, promptly refer to specialists (eg, in neuropsychology, neurology, rehabilitation, sports medicine, pain management, education, behavioral health)

social, athletic, school, and family issues are all addressed adequately.

No comprehensive management guidelines and conspicuously few research studies have been published that focus specifically on sport-related concussion in the pediatric population. To date, however, >20 different published expert guidelines geared toward managing athletic concussion more generally have appeared, including those from Robert C. Cantu, MD,^{75,76} the Colorado Medical Society,⁷⁷ the American Academy of Neurology,⁵ and the recently convened Concussion in Sport Group (CISG).^{78,79} In addition, many clinically oriented literature reviews,⁸⁰⁻⁸⁴ several relevant books,⁸⁵⁻⁸⁷ and a number of journal issues⁸⁸⁻⁹⁰ have been devoted entirely to concussion. The American Academy of Pediatrics has also published a practice parameter for the general management of minor closed head injury in children⁹¹ and has endorsed the sport-specific, but not child-specific, guidelines generated by the American Orthopaedic Society for Sports Medicine Concussion Workshop Group.⁹²

All of these publications can clearly help direct the clinical care of the young athlete. What follows is a summary of much of the current consensus for managing the concussed athlete at any age, with special atten-

tion devoted to the young athlete in particular. Table 1 provides an overview of a number of the relevant clinical management areas.

Preparticipation Assessment and Prevention

Before participation in organized sports, medical examination is frequently mandated and certainly advisable.^{93,94} For the pediatric athlete, the influential role that parents play dictates that they need to be active participants as well. Because no proven medical treatment exists for mTBI once it occurs, a central goal of the preseason contact should be concussion prevention. In this regard, a number of general and sport-specific resources are available to the pediatric clinician that describe techniques, training procedures, rules, and equipment aimed at preventing concussive injuries. Table 2 highlights several of these resources, which should be considered credible but not necessarily empirically supported.

Another essential ingredient of the preparticipation medical examination is providing education to help guide the accurate recognition of concussions. Many athletes still do not recognize or report concussive injuries.^{95,96} In this context, it is worth stating (again and again!) to every player, parent, and athletic staff member that loss of consciousness is not the only indication that an athlete has suffered a concussion. In fact, most sports participants who sustain concussions never lose consciousness.⁹⁷ Furthermore, loss of consciousness in iso-

TABLE 2 Concussion Prevention Resources

Bicycle Helmet Safety Institute
Clearinghouse Web site and technical resource for helmet information
www.helmets.org; 703-486-0100
Brain Injury Association of America
General information about head injury prevention, as well as brain injuries in several sports
www.biausa.org; 800-444-6443
Canada's National Brain and Spinal Cord Injury Prevention Foundation
Includes awareness and education program focused specifically on concussion; "smart hockey" videotapes designed to prevent concussion are available for purchase
www.thinkfirst.ca; 800-335-6076
Centers for Disease Control and Prevention
Wealth of brain injury information including free concussion fact sheets for athletes through the recently released high school coaches' tool kit
www.cdc.gov/ncipc/tbi/coaches_tool_kit.htm
National Safe Kids Campaign
Dedicated to the prevention of all unintentional childhood injury; available fact sheets are focused on sports and recreational injuries
www.safekids.org; 202-662-0600
National Youth Sports Safety Foundation
Educational organization focused on reducing injuries in youth sports; sports-safety fact sheets are available for purchase
www.nyssf.org; 617-277-1171
Pashby Sports Safety Fund Concussion Site
Web site devoted to providing education about concussion specifically, including proper recognition and prevention tips
www.concussionsafety.com

lation can be a relatively poor predictor of neurobehavioral outcome.⁹⁸⁻¹⁰⁰

Physicians should also highlight the rationale and need for immediate reporting of concussion. Because many teenagers have a sense of invulnerability,¹⁰¹ they will especially benefit from a personalized, thought-provoking message explaining the reasons that keeping quiet about a concussion and “toughing it out” are wrongheaded.

In addition, preparticipation medical contact should incorporate a history taken with both parent and child, delineating the number of prior concussions, timing and severity of each, and duration and intensity of any resulting symptoms. Simply asking about previous concussions is insufficient, because underreporting is common without a structured symptom-based assessment.¹⁰² For the sake of comparison if a concussion occurs during the season, preinjury data should be collected regarding the athlete’s typical level of “postconcussive” symptoms (headaches, nausea, etc). McCrory¹⁰³ offers a convenient clinical baseline assessment form to facilitate the documentation of this information.

Acute or On-site Evaluation

Acute management of any athlete who has sustained a head injury begins with the ABCs of first aid: ensuring that airway, breathing, and circulation are intact.⁹² Although quite rare, concussive blows can be associated with serious pathology including cervical spinal injury, skull fracture, and all 4 types of intracranial hemorrhage (ie, epidural, subdural, intracerebral, and subarachnoid).^{42,104} Exclusion of these medical emergencies is paramount during the on-field assessment, for which various guidelines are available.¹⁰⁵⁻¹⁰⁷ Specific concussion-severity markers also need to be considered. Because informal mental status testing (eg, Where are you? What day is it?) has not been found to be very sensitive to concussions, standardized field-based cognitive screening is necessary.¹⁰⁸ A number of tools have been designed for this task, including the commonly used Standardized Assessment of Concussion, which is a brief, well-validated instrument that can be administered on the sideline in ~5 minutes and has published normative data for junior high and older athletes.¹⁰⁹

Subsequent Medical Evaluation

During postconcussion medical follow-up, the primary health care provider needs to update the injury history and carefully examine the athlete for indications of intracranial injury. Strength, sensation, coordination, reflexes, and “soft” neurologic signs all should be evaluated.¹¹⁰ After mTBI, the exact conditions warranting neuroimaging are controversial and continue to be debated.¹¹¹⁻¹¹⁴ Cantu¹¹⁵ practically recommends neuroimaging in the context of loss of consciousness for greater than a few seconds, prolonged impairment of conscious

state, mental status deterioration, dramatic worsening of headache, focal neurologic deficit, seizure activity, or persistence or worsening of PCS over time.

Mild TBI does not consistently result in abnormalities on either structural neuroimaging^{116,117} or neurologic examination^{118,119}; thus, the pediatric clinician should be mindful that objective medical data will often be lacking. It is important to note that when balance concerns are apparent, formal postural-stability testing could contribute additional information to the physical examination. Such testing has shown promise as a means to more objectively evaluate the balance deficits that are seen soon after injury in certain athletes.¹²⁰

Because objective medical evidence is often lacking postconcussion, systematic review of symptoms as reported by both the athlete and parent is an indispensable part of any follow-up medical contact. Although no published measures focus exclusively on the pediatric population, multiple PCS checklists and scales have been developed to assist with this undertaking.¹²¹⁻¹²³ The Concussion Symptom Inventory (CSI) is a recently developed empirically based PCS measure that could be readily used by the primary care provider. The Concussion Symptom Index (see Table 3) was derived from >16 000 high school and college athletes and includes normative data from >600 athletes with concussion. PCS are not unusual among individuals without concussion.¹²⁴ Consequently, all reports of PCS need to be interpreted in view of the overall clinical evaluation, using preinjury data when available. The crux of the PCS postinjury investigation is change in an individual’s functioning, not the presence or absence of any particular symptoms, because no pathognomonic profile of PCS exists and each athlete’s presentation will differ to some extent.

Neuropsychological Evaluation

For both pediatric and adult populations, conventional neuropsychological assessment is a well-established, recommended methodology for evaluating individuals who

TABLE 3 Concussion Symptom Index

Symptom	Absent	Present
Headache	0	1
Nausea	0	1
Balance problems/dizziness	0	1
Fatigue	0	1
Drowsiness	0	1
Feeling like “in a fog”	0	1
Difficulty concentrating	0	1
Difficulty remembering	0	1
Sensitivity to light	0	1
Sensitivity to noise	0	1
Blurred vision	0	1
Feeling slowed down	0	1
Total		

Source: C. Randolph, PhD, Loyola University Medical Center, written communication, 2005.

have sustained neurologic injury or who have neurodevelopmental problems.^{125–127} Neuropsychological assessment can objectively identify cognitive, psychosocial, and achievement difficulties and assist with differential diagnosis and clinical management. In the sports arena, however, the general use of comprehensive neuropsychological evaluations is impractical, because traditional testing takes multiple hours to complete and is priced accordingly.

Thus, in the 1980s, a model of abbreviated “baseline” neuropsychological testing was introduced specifically for athletic purposes.⁸⁰ The model calls for preinjury or baseline neurocognitive testing lasting ~30 minutes, followed by postinjury comparison testing for athletes who sustain concussions during the season. The model has been popularized recently as the most sensitive means of documenting the neurocognitive effects of concussion and is now used by a number of professional, collegiate, and high school programs.^{78,122,128} The typical baseline battery originally consisted of paper-and-pencil instruments. More recently, computerized tests have been increasingly used, because they are thought to have a number of potential advantages over paper-and-pencil measures.¹²⁹ Three computerized programs are now available commercially: the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT Applications, Inc, Pittsburgh, PA), Concussion Resolution Index (Headminder, Inc, New York, NY), and CogSport (Cogstate Ltd, Victoria, Australia). The Automated Neuropsychological Assessment Metrics is a computerized program available free of charge through work sponsored by the US government.

In theory, baseline neuropsychological testing could provide incremental information to assist in decisions about return to play, because cognitive and somatic problems are not perfectly correlated after concussion and standardized testing may be more objective than merely asking an athlete if he or she is still experiencing cognitive problems.^{130–132} Nonetheless, the baseline model has a number of methodologic and statistical problems that are not resolved yet.^{133,134} Moreover, a recent comprehensive review of the psychometric properties of the commonly used paper-and-pencil and computerized measures raises serious questions about whether the instruments are well validated enough to support their applied clinical use at this time.¹³⁵ Sufficient data regarding the reliability, validity, and clinical utility of the neuropsychological instruments within the baseline model are still lacking.

Multiple studies have actually shown that neuropsychological testing can be sensitive to the acute neurocognitive effects of sport-related concussion,^{98,99,132,136–149} a fact that has likely led various experts and groups (eg, the CISG, National Athletic Trainers’ Association) to endorse the use of baseline neuropsychological testing when making return-to-play decisions in certain situa-

tions.^{79,106} However, no identified prospective, controlled study has shown that athletes display neurocognitive impairment after symptoms have resolved as measured by a simple PCS checklist. In fact, methodologically rigorous studies have failed to detect differences on neuropsychological testing 1 to 2 weeks postinjury, a finding corroborated by a recent meta-analysis that evaluated the neuropsychological impact of athletic concussion in 21 studies.¹⁵⁰ These data need careful consideration when examining the empirical merit of postinjury neuropsychological testing across populations, because such testing does not add value to return-to-play decisions when athletes are still symptomatic.⁷⁹ If symptoms are being reported, no expert guideline would allow a return to play, and thus neuropsychological testing is unnecessary in this situation (at least for the purpose of the return-to-play decision).

Because of these statistical and methodologic issues, Randolph et al¹³⁵ argue that the clinical implementation of baseline neuropsychological testing remains premature. Although we recognize that this conclusion contrasts with the position taken by a number of other authorities in the field, we agree that sound scientific data have yet to justify the financial costs, time, and energy needed to implement baseline neuropsychological testing for pediatric athletes or demonstrate that such testing actually leads to a reduction in the risks associated with returning young athletes to play. Until these data become available, neuropsychological testing within the baseline model should be considered an investigational methodology for pediatric athletes, certainly worthy of ongoing research but not yet ready for general clinical use in making individual decisions regarding return to play.

Despite the current limitations of neuropsychological assessment for the specific decision about return to play, experts agree that such testing does have a role in evaluating and managing certain athletes postinjury. For instance, athletes who have sustained multiple concussions or whose recovery is not progressing in a typical fashion (ie, symptom clearance within 1–2 weeks) could benefit from a thorough neuropsychological evaluation. This type of assessment can help to document impairment and identify factors that could be contributing to lingering difficulties. Because most pediatric athletes are expected to meet the cognitive demands of school soon after injury, neuropsychological evaluation in this population has the additional benefit of being able to identify cognitive deficits and assist in the development of appropriate educational management plans regardless of decisions about return to play.

When to Return to Play

When to return an athlete to play after a concussion has been the subject of much discussion and controversy, although authors agree that the decision should be ap-

proached with due caution. Justification for this caution has commonly reflected 2 ideas: that repeated concussions have cumulative effects and that they result in increased vulnerability to additional injury. Both ideas are gathering empirical support. Recent clinical studies have demonstrated a cumulative neurocognitive, somatic, and neurophysiologic effect of repeated concussion^{151–155} (but see also work by Guskiewicz¹⁵⁶ and MacCocchi et al¹⁵⁷). Experiments with animals are consistent with the possibility of cumulative effects^{158–161} and suggest that the hippocampus could be particularly vulnerable to repeated mild injury.¹⁶² Athletes who have sustained previous concussions have also been found to be 3 to 6 times more vulnerable to future injury, perhaps in part secondary to a premature return to play.^{154,163}

In the pediatric athlete, a number of additional reasons exist to suggest that the return-to-play decision should be made with ample care. First, we do not yet have a clear understanding of how repeated brain insult could change neurobiological or neurobehavioral development over the long run. Second, the risk-benefit analysis in younger athletes is often considerably different from that in adults, weighted much more heavily toward potential loss or future functional disruption as opposed to immediate gain from returning to competition. Third, although extremely rare, second-impact syndrome has been documented almost exclusively in immature brains, suggesting that the young athlete is at heightened risk for the potentially catastrophic consequences that have been reported after repeated injury.

For all athletes, the existing guidelines regarding return to play have undeniably helped increase awareness and systematize the management of concussive injury. Nevertheless, at present, none of the guidelines have gained sufficient scientific support to become the universally accepted “gold standard.”¹⁶⁴ The number and inevitable divergence of the existing guidelines make the need for consensus opinion especially pressing. In this regard, a panel of international sports concussion experts (referred to as the CISG) has been convened twice, in 2001 in Vienna⁷⁸ and in 2004 in Prague.⁷⁹ Based on available data, the group has agreed that no athlete should return to play while still symptomatic from a concussion physically, cognitively, or behaviorally. Experts agree that the earliest an athlete should return is when:

- no signs or symptoms of any kind are apparent at rest or during exertion;
- neurologic examination is normal; and
- neuroimaging is unremarkable when performed.

We have no reason to suspect that pediatric athletes should be managed differently, with the only possible exception being the need for even more conservatism.

One example of this more conservative approach would be to always remove the young athlete from the day’s competition after a concussion and not allow return to play until cleared medically, regardless of initial injury severity. This recommendation would differ from many current guidelines, which allow for return to play during the same competition if the athlete is asymptomatic after 15 to 20 minutes. In contrast to the professional athlete for whom this might be appropriate,¹⁶⁵ research suggests that such rapid return is likely too liberal for the younger athlete. Lovell et al^{137,148} have found that high school athletes sustaining grade I or mild “ding” injuries, who are generally free of obvious symptoms on the field, display an evolving symptom complex that can last for days postinjury.

For multiple reasons, in the context of pediatric concussion return-to-play decisions, we should abide by the adage “when in doubt, sit them out!”

How to Return to Play

How to return an athlete to play has also been considered by the CISG.^{78,79} Because of possible symptom aggravation with increased levels of exertion,¹⁶⁶ the group consensus is that an athlete should return to play in a gradual, stepwise fashion rather than in a more abrupt manner (ie, out 1 day, return to play the next). Once an athlete is judged free of all symptoms at rest, the group recommends a progression through a sequence of steps, with the athlete needing to remain symptom-free without medication throughout each step before proceeding and returning to play.

1. Light aerobic activity (eg, walking, stationary bike)
2. Sport-specific activities and training (eg, running in soccer, skating in hockey)
3. Noncontact training drills
4. Full-contact practice training after medical clearance
5. Game play

The Special Case of Retirement

When physicians should recommend seasonal or lifetime retirement to an athlete is an area especially devoid of empirical data, although several authors have highlighted important points to consider.^{167–169} This issue has not been addressed specifically with reference to the pediatric athlete, but again a conservative approach is inarguably appropriate, and both parents and youth need to be actively engaged in the decision-making process.

As highlighted above, contraindications to return to play include ongoing symptoms, abnormalities on neurologic examination, or positive neuroimaging findings. Clear evidence of impairment on neuropsychological testing may indicate ongoing cognitive problems and

thus could support a recommendation for retirement as well. Other potential reasons to consider disqualification include evidence of an increasingly prolonged recovery course after successive injuries and less force being needed to cause concussions or lasting symptoms.¹⁶⁷ Even without evidence of cumulative injury or ongoing symptoms, most expert guidelines recommend disqualification for athletes who sustain multiple concussions in 1 season, a recommendation that is without clear scientific validation¹⁶⁹ but has intuitive appeal when dealing with the developing brain of a young athlete. If retirement or seasonal disqualification is deliberated but ultimately deemed inappropriate, consideration could still be given to recommending other options that would lessen the young athlete's risk of concussion, including changing sports, positions, or style of play (eg, changing from football to baseball, from quarterback to punter, from aggressive to more cautious skiing).

Non-Sport-Specific Considerations

To truly ensure optimal recovery after concussion in children and teens, clinicians need to be broadminded and consider not only the sport-specific plan but also the interventions and supports needed outside the athletic arena. As stated earlier, the outcome of most uncomplicated pediatric concussions is quite positive. However, parents, school personnel, and athletic staff need to know what symptoms to look out for and adjust expectations accordingly when ongoing problems are apparent. The simple act of providing education about commonly seen symptoms is known to reduce the negative effects associated with pediatric mTBI.¹⁷⁰ Thus, one appropriate intervention involves giving families and school personnel relevant information such as the free Centers for Disease Control and Prevention concussion fact booklet (available at www.cdc.gov/ncipc/tbi).

Similar to other aspects of concussion care, managing the transition back to school will depend on the individual circumstances of each athlete. If specialized educational help is deemed necessary, it can be obtained in 3 ways within the school system: (1) informal accommodations; (2) Section 504 plans (a civil rights entitlement to ensure nondiscrimination of students with disabilities); and (3) Individualized Education Programs (a tailored educational plan obtained through the special education system).

A few informal accommodations and modifications in the first days or weeks after injury will suffice for many symptomatic athletes as they go back to school. The smaller minority with lasting or severe problems are apt to benefit from more formal intervention, for which a Section 504 plan is often appropriate. After mTBI, few children will need an Individualized Education Program, although federal law dictates that special education services should be made available if the injury resulted in

TABLE 4 Potential Strategies to Support the Transition Back to School After Concussion

Initial transitional support
School personnel alerted to injury and potential consequences
Reintegration into school occurs gradually
Student not expected to do all work completed in absence
Extra assistance provided to facilitate completion of makeup work
General school-based support
Monitor student carefully for a period of 2–3 mo
Ensure rest time and breaks available as needed
Reduce overall homework and class workload
Reduce cognitively demanding in-school tasks (eg, no more than 1 test each day)
Specific classroom-based support
Delay standardized and classroom tests
Waive time constraints for tests
Increase flexibility for assignment due dates
Provide preferential seating to allow for closer monitoring and decreased distractions
Allow access to a model peer's or teacher's notes

difficulties that negatively impact the ability to make appropriate educational progress.¹⁷¹

Parents and primary care providers should alert educational personnel to the injury, potential consequences, and need for close monitoring. In addition, they should ensure that children are not rushed back too quickly after concussion to avoid undue fatigue and frustration. Children with concussion may need to make the transition back to school gradually. At the same time, keeping a child home from school without sufficient cause also entails risks. Thus, each case requires prudent consideration. Additional recommendations for managing the school transition after mTBI are available.^{172–174} Clinically, we have found the strategies listed in Table 4 to be helpful. In some cases, neuropsychological evaluation can also assist with detailing the specific symptom and cognitive profile for a student who has suffered a concussion and can help to ensure that suitable supports are provided at school and that appropriate education and guidance is provided to families and educators.

From a medical perspective, most postconcussive problems will resolve relatively quickly without treatment. For those that do not, many therapeutic options are available to the treating clinician, including pharmacologic intervention.^{175–178} However, aside from psychological studies that support the benefits of early education, reassurance, and positive coping, little pertinent intervention research has been conducted.^{179,180} Thus, the clinician is faced with the need to examine the child who has been injured systematically and to treat symptomatically using methods that have been demonstrated to be effective largely in nonconcussed populations. Of course, all medical problems require ongoing evaluation, not only to rule out more serious pathology but also because certain symptoms can occur or persist that suggest a secondary or unrelated problem that will need

additional assessment (eg, depression, anxiety, family dysfunction, learning disability, attention-deficit/hyperactivity disorder).

In general, the pediatric practitioner should expect a positive outcome after concussion (ie, the norm for children and teenagers is not a lasting "postconcussion syndrome"). When the outcome is less positive, the pediatrician should consider referrals to specialists in neuropsychology, neurology, rehabilitation, sports medicine, pain management, education, and behavioral health, all of whom could be useful in identifying and treating injury- and non-injury-related factors that may be interfering with recovery.

CONCLUSIONS

The sport-related concussion story for the adult competitive athlete has been unfolding with impressive rapidity in recent years, driven by a remarkable amount of work by numerous groups of researchers around the globe. Conversely, thus far, little work has focused on the young athlete. As a result, the pediatric sport-related concussion story remains largely untold. Nevertheless, drawing from extant research and expert opinion, today's pediatric health care provider has much more information available to inform clinical management than was the case even a few years back.

We know that concussions will occur relatively frequently among children and adolescents and that younger athletes may respond more poorly to such injuries, in very rare cases catastrophically so. Given the substantial individual variation in responses to concussions, most experts would now agree that the initial "grade" of a concussion is less important than the systematic tracking of each athlete's recovery course over time. Because accurate neurobiological markers do not exist yet, the most sophisticated way to track recovery at present is through serial physical examination and standardized behavioral instrumentation (eg, PCS rating scales). Although neuropsychological testing could potentially contribute to tracking recovery from concussion, at present the empirical evidence is not sufficient to support its routine clinical use for return-to-play decision-making within a baseline model. However, neuropsychological evaluation is recommended for athletes who have sustained multiple injuries or whose recovery is not proceeding as expected, because such testing can help to document impairment, identify factors interfering with progress, and facilitate the development of appropriate management plans. Consensus opinion continues to affirm that no athlete should return to play while he or she is symptomatic. Until data convincingly suggest otherwise, this directive should certainly apply to the young athlete, for whom a conservative approach to management should be the rule when making decisions about return to play. Finally, we know that proven medical treatments for concussion have not been estab-

lished and that misinformation and underreporting of concussion still pervade athletics. Primary care providers working with the pediatric population are uniquely positioned in this regard: by devoting sufficient time and attention early in an athlete's career, they can help cultivate a lifelong appreciation for concussion prevention and promote the wherewithal to accurately recognize and swiftly report such injury.

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