# Concussion Management in the Child and Adolescent Athlete

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LOVELL, M.R., and V. FAZIO. Concussion management in the child and adolescent athlete. *Curr. Sports Med. Rep.*, Vol. 7, No. 1, pp. 12–15, 2008. *This article reviews the status of concussion management in child and adolescent athletes. Children and adolescent athletes represent a distinct group from adult athletes, although past concussion guidelines have not specifically addressed these differences. It is the position of this article that younger athletes need to be considered as a separate group and that conservative management of concussion is often called for. Neurodevelopmental differences between adult and child athletes are highlighted and new developments in the management of concussion in youth sports are discussed.*

## INTRODUCTION

A recently published estimate suggests that 30 million or more children and adolescents currently participate in organized sports across the United States (1). With large numbers of children and adolescents participating in sports and increased recognition of injuries, there has been a corresponding increase in reported injuries over the past decade. This increase in injuries has been accompanied by an increased focus on the development of new techniques aimed at improved injury management.

Mild traumatic brain injury or "concussion" is a common injury in athletes of all ages, including children. In fact, concussion has most recently been estimated to occur in 1.6 to 3.6 million young athletes per year (2). Further, by the time adolescents reach high school, more than half (53%) report a history of concussion, and in the college population, 36% report a history of multiple concussions (3). One recent study found that concussion injury is as much as 6 times more likely to happen in organized sports activity than other activities in children between the ages 6 and 16 yr (4). Given this backdrop, it is somewhat surprising that the scientific study of concussion in children has been limited to only a handful of studies. The purpose of this article is to review the status of concussion management in children and to suggest future avenues for research and ultimately for clinical care.

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## THE NATURE OF THE PROBLEM: PATHOPHYSIOLOGY OF CONCUSSION IN THE YOUNG ATHLETE

Although evidence has suggested for years that children might be more vulnerable to the effects of brain injury than adults (5,6), the systematic study of the pathophysiology of sports-related concussion is a very recent endeavor, with the vast majority of research taking place over the past decade. The initial research of Hovda and colleagues (7) has been exceedingly important in establishing that specific changes occur at the cellular level following experimentally induced concussion. In addition, Hovda and colleagues have established that there may be increased vulnerability to injury during the acute recovery period (7–14 d) if there is additional injury to the brain during this time. Hovda further postulated that a "metabolic mismatch" between brain glucose utilization and cerebral blood flow was at least partially responsible for this increased vulnerability (7). More specifically with regard to the potential importance of age in recovery from concussion, Prins found that the younger rat brain may be more vulnerable to injury, related to hypotension following injury (8). More recent animal research by Vagnozzi and colleagues also has suggested that the brain is more vulnerable to additional injury after an initial concussive injury (9). These recent research findings from animal experiments have been used to help explain the rare but potentially fatal "second impact syndrome" (5) that occurs only in children under the age of 18.

Although the concept of second impact syndrome is somewhat controversial and has been called into question (10), few researchers or clinicians who have experience in working with children would deny that children represent a distinct clinical group and should not simply be regarded as "little adults." However, our understanding of the neurophysiological differences between children and adults remains far from complete on both the research and clinical levels.

The scope of Hovda's initial research was somewhat limited given its focus on infrahuman subjects (rodents). However, with the advent of new functional neuroimaging techniques, new research is emerging that indicates that neurophysiological changes can be directly linked to clinical recovery in children. Functional magnetic resonance imaging (fMRI) is ideally suited for use in children because it is noninvasive, involves no exposure to radiation like other imaging technologies [*e.g.*, positron emission tomography (PET)], and allows for the direct assessment of specific brain areas during "in scanner" neuropsychological testing. Therefore, fMRI allows for the simultaneous evaluation of both neurophysiological and neuropsychological aspects of recovery from concussion. In a recently completed multi-year NIH-funded study of high school athletes, Lovell and colleagues at the University of Pittsburgh found that the degree of activation in frontal brain areas in acutely concussed athletes was related to time of clinical recovery: adolescent athletes (average age of 16 yr) who demonstrated initial hyperactivation in the frontal cortex took approximately twice as long to meet clinical recovery criteria (*i.e.*, normal neuropsychological test results and no self-reported symptoms), compared with a concussed group without hyperactivation and an age-matched athlete control group (11). More specifically, this study found a close relationship between changes in cerebral blood flow and performance on the Immediate Post Concussion Assessment and Cognitive Testing (ImPACT) computer-based neuropsychological test battery. Unfortunately, there are no parallel studies of pre-high school athletes upon which to evaluate specific age-related changes. We are hopeful that future studies of this nature will help establish similarities and differences between child and adult athletes and will therefore help to guide the future development of age-specific treatment guidelines (12).

## CLINICAL RECOVERY IN THE CHILD OR ADOLESCENT ATHLETE

As suggested previously, most studies on concussion in younger athletes have focused on the adolescent population and not on younger children. This is not surprising given that nearly 60% of high school students participate in sports activities (13). Additionally, it has been logistically difficult to conduct prospective studies of young children as these athletes most often participate at the recreational level, and there is no systematic medical oversight or trained personnel "on-field" when the injuries occur.

Diagnosis of sport-related concussion typically occurs when an athlete demonstrates any mental status change after a traumatic force to the head or body (14). In the younger athlete (*i.e.*, below high school age), trained personnel are often not present, and the identification of the injury is dependent upon the medical knowledge of the parents or coaches (or lack thereof) who are in attendance at the particular sporting event. Obviously, this is a less than optimal situation.

Once a young athlete sustains a blow that can result in a concussion, he or she may experience acute signs of injury that include loss of consciousness, anterograde, post-traumatic, or retrograde amnesia, and disorientation. Determination of whether these markers of injury are present requires careful evaluation, and this task may be quite difficult in the younger athlete who has incompletely developed conceptual and communication skills. These acute markers can yield crucial information about the severity of the concussion, as found in a study of adolescent athletes by Collin *et al.* (15). In this study, results indicated that the presence of retrograde amnesia indicated poor outcomes, that is, higher symptom scores and decreased neurocognitive data, acutely post-injury. Additionally, those who experience post-traumatic amnesia with mental status change also had poor outcomes acutely post-injury. This study provides evidence that amnesia can indicate a more severe injury in adolescents and a worse presentation acutely following the injury. This evidence has implications for clinical assessment.

Initial post-concussion symptoms as well as concussion history also have been found to play a role in severity of the injury and neurocognitive deficits. One study, which examined symptoms of concussion in high school athletes, found that subjective "fogginess," a symptom related to neurocognitive functioning, was related to increased symptom scores as compared with those who did not experience this symptom. Additionally, those athletes reporting fogginess also had significantly lower scores on measures of memory functioning, processing speed, and reaction time (16).

The process of recovery after concussion in children may be complicated by a number of factors including but not limited to severity of injury and prior concussion history. In addition, age of the athlete has been suggested to be an important factor. Although several studies have suggested that collegiate athletes usually recover within 1–2 wk of injury (17), recent research indicates that younger athletes may take considerably longer to recover. For instance, in an investigation of high school football players by Collins *et al.* (18), at least 25% of the group took up to 4 wk to reach recovery criteria. Varying rates of recovery, especially in children and adolescents, is common in concussion, and research has indicated that a multitude of factors affect the rate in which a child recovers. It has been our clinical experience that athletes who are in elementary or middle school often require up to 1 month to become symptom-free.

## MANAGEMENT OF CHILD AND ADULT ATHLETES: DOES AGE MATTER?

During the 1980s and 1990s, over 20 different concussion management guidelines were published with the intent of providing directive for the safe return to play of the concussed athlete. Surprisingly however, none of these guidelines provided age-specific management directives and can best be described as "one size fits all." More recently, there has been an increased awareness of the need for guidelines that recognize specific issues relevant to a given age group. In 2004, the Prague International Concussion Meeting was the first consensus conference of its kind to specifically recognize the need for the development of age-specific guidelines (19).

It is our contention that age-specific guidelines are sorely needed and that a number of emerging research studies support this need. As mentioned previously, conditions such as second impact syndrome point to potential dangers that are specific to children and adolescents. In addition, relatively recent research also has suggested that younger athletes may recover at a different rate than older athletes. For example, Field and colleagues (3) found that a group of concussed high school athletes recovered more slowly (as per neuropsychological test results) compared with a group of college athletes. Along similar lines, Pellman (20) found that a group of NFL athletes recovered on average within 2–3 d compared with a group of high school athletes, who often required a week or more. Moreover, the athletes with a history of multiple concussions reported more symptoms at their baseline evaluations (evaluation pre-season, presumably before a concussion occurs) (16,21). Finally, it has recently been suggested that younger brains may be more vulnerable to injury since they are still undergoing the developmental process and have a decreased number of compensatory skills (22).

## DEVELOPMENT OF NEUROCOGNITIVE TOOLS TO ASSESS YOUNGER CHILDREN (AGES 5–11)

It is important to note that most literature regarding concussion does not currently extend to children of younger ages, specifically those in middle school or younger. However, due to the high rate of concussion in this group, research to develop and validate post-concussion cognitive testing for younger children (ages 5–11 yr) has recently been supported by the U.S. Centers for Disease Control and Prevention (Gioia, G., personal communication, 2007). This effort had focused on modifying the existing computerized test battery (ImPACT), which has been shown to be a valid and reliable measure of post-concussion neurocognitive deficits in high school, collegiate, and professional athletes (23,24).

The pediatric version of ImPACT is presented in a video game format and will be available for more widespread use within the next 1–2 yr. Unfortunately, the current evaluation of younger children has been limited to observation by parents and physicians, as well as the self-report of symptoms by the child. Given the limited communication capabilities of younger children, determining whether they have experienced or are experiencing post-concussive sequelae can be a challenging task. We are hopeful that increasing attention will be directed to the creation and validation of new evaluation tools for this group over the next 5 yr.

## FUTURE DIRECTIONS

Clearly there is a dearth of literature with regard to younger children and concussion, therefore, future directions of research should focus on developing methods of clinical assessment for younger children. Children now participate in youth sports as young as 3 yr old, and therefore one could assume that the risk for sustaining a concussion in sport-related activity is present for younger children at somewhat similar rates as adolescents. Guidelines and literature regarding management of concussion in adolescents has to be clinically adapted for children in a systemic way. More specifically, neurocognitive assessment tools continue to be needed, and the reliability and validity of the tasks need to be firmly established. Additionally, research in younger children should focus upon symptom presentations that may be specific to certain age groups and to understanding factors that might affect recovery in the younger age ranges.

Literature on adolescent athletes is more available, but is still relatively limited. While history of concussion has been shown to have an affect on symptom presentation at baseline and post-concussion and also on post-concussion neurocognitive testing, it is unclear at what point a concussed athlete is considered more vulnerable to injury (16). Information regarding vulnerability in high school athletes (and children) would be integral to return to play decisions. Similarly, research to date has not investigated familial factors that may play a role in vulnerability and recovery time. Familial factors include family history of headaches, and neurological disorders, among others, but there also may be genetic factors that affect vulnerability to and recovery from concussion.

## CONCLUSION

In recent years, concussion in younger athletes has received some initial attention both in the lay press and within the sports medicine community. However, to date, athletes below the high school level have not been studied extensively, and there is much that we do not understand regarding specific risk factors, expected recovery patterns, and the long-term consequences of injury. While some limited research is available regarding this injury in adolescents, many more topic areas have yet to be explored. Participation in sports in the younger age ranges has increased significantly over the past decade and promises to continue to gain in popularity in the coming years. We are therefore hopeful that research with this group will continue to expand to meet the challenge of shaping clinical care in the younger athlete.

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