Selected Issues in Pediatric Sports Medicine Practice in USA

DILIP R PATEL*

*Department of Pediatric and Adolescent Medicine, Western Michigan University Homer Stryker, M.D., School of Medicine, Michigan, USA

Participation in sports by children in the United States over the past 3 decades has seen a move from spontaneous and fun activity by children and adolescents to a more organized and competitive activity largely governed by adults and sports governing organizations. With this shift we have also seen a trend in participation in organized sports at younger age, increase in intensity in activity level, and specialization in a single sport from an early age. These and other factors contribute to an increased incidence of sport related overuse injuries in children and adolescents. Another area of intense debate and scrutiny is the long term neurocognitive impact in adolescents of sport-related concussions. Recognition of adverse long term impact of sport related concussions on developing brain has resulted in increased education efforts, prevention strategies, and legislative activity. Screening of young athletes for cardiovascular disease to prevent sudden cardiac death also continues to be a subject of ongoing intense debate in the United States.

Key words: concussions, cardiovascular screening, neurodevelopment, sport readiness, neuroimaging

Sport-related concussions

According to the United States Centers for Disease Control and Prevention the concussion rates in the United States, among 10–19 year olds increased by nearly 100,000 annually in 2009 compared with 2001, concussions represent 6% of all collegiate sports injuries, and 9% of high school athletic injuries\(^1\). Considering that 50 million American children and adolescents participate in team sports annually head injuries in sports are a major epidemic\(^1\).

Kamitani, et al (2013), looked at the epidemiology of catastrophic head and neck injuries in judo in Japan\(^2\). The authors analyzed the accident reports submitted to the All Japan Judo Federation’s System for Compensation for Loss or Damage and found a total of 72 judo injuries (30 head, 19 neck, and 23 other injuries) reported between 2003 and 2010. Kamitani, et al (2013) found that, among the reported head injuries, 90% occurred in players younger than 20 years of age\(^2\). Acute subdural hematoma was found in 94% of head injuries. In players who sustained neck injuries, 18 players had cervical spine injury, 11 of whom had fracture-dislocation of the cervical vertebra. The findings showed that the neck injuries were associated with having more experience and executing offensive maneuvers; whereas, head injuries were associated with age younger than 20 years and with being thrown\(^2\).

According to Kamitani and colleagues (2013), many head injuries occurred when players were thrown to the mat on their back\(^3\). Among neck injury cases, 60% occurred when a player attempted to throw an opponent, and 40% occurred while a player was being thrown. This was attributed to deficient skills of beginners. It is of interest to note that, severe judo-related head injuries have not been reported in the United States, Canada, Germany, France, or Australia as they are reported in Japan. One reason cited for this is that in Japan, unlike other countries, until 2011, there was no qualification system for judo
instructors that includes knowledge of safety guidance\textsuperscript{2}). In Japan, martial arts have been compulsory in junior high education since 2012. This has raised concern about increased head and neck injuries. Proper education programs and practice have been promoted as possible strategies in preventing catastrophic injuries.

1. Current evaluation and management guidelines for concussions

The Zurich consensus statement and the American Academy of Neurology concussion guidelines are the most widely used practice guidelines for evaluation and management of concussion; both have a similar general approach\textsuperscript{3-5}.

The key elements of the Zurich guidelines definition of concussion include the following\textsuperscript{3}:

• Concussion is a brain injury and is defined as a complex pathophysiological process affecting the brain, induced by biomechanical forces.
• Concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an “impulsive” force transmitted to the head.
• Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously.
• In some cases, symptoms and signs may evolve over a number of minutes to hours.
• The acute clinical symptoms largely reflect a functional disturbance rather than a structural injury.
• No abnormality is seen on standard structural neuroimaging studies.
• Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness.
• Resolution of the clinical and cognitive symptoms typically follows a sequential course. The majority (80–90\%) of concussions resolve in a short (7–10 day) period, although the recovery time may be longer in children and adolescents.

The Zurich guidelines stipulate a graduated return to play over a period of 7–10 days in most cases\textsuperscript{3}. For athlete to return to play he or she must be completely symptom free and must have a normal physical and neurological examination. One area that is of special significance here is the concept of cognitive rest\textsuperscript{3,5}. Many young athletes find cognitive difficulties following concussion. Studies have shown that difficulty in school work include taking standardized tests, and particular difficulty in mathematics and science classes\textsuperscript{5}. Prolonged periods of reading many also aggravate concussion symptoms. Cognitive rest has been shown to improve recovery. The athletes should refrain from television watching, video games or texting. The school should be informed of the concussion and the student athletes be allowed to have lighter school work including assignments and test requirements\textsuperscript{5}. The school work should gradually progress to previous levels and this may takes several weeks to sometime months.

2. Modulating factors with special reference to age

Zurich guidelines and others have described factors that may modify the risk of concussion and duration of recovery as shown here\textsuperscript{3,5-8}. Although loss of consciousness (LOC) is not a criteria for concussion, prolonged LOC (more than 1 minute) has been shown to increase the duration of recovery\textsuperscript{3}. Young age has been shown in some studies to increase the risk for long term neurocognitive deficits as well as prolong duration of recovery from concussion\textsuperscript{3,6,8}. Neurocognitive deficits are of significant concern in those with repeated concussions and concussions that occur close to each other\textsuperscript{3,8}.

Morgan \textit{et al} (2015), looked at the risk factors for post-concussion syndrome (PCS)\textsuperscript{7}. The authors aimed to identify risk factors for PCS development in a cohort of exclusively athletes 9–18 years of age who sustained sport-related concussions (SRC). They identified 40 patients with PCS and matched them by age at injury and sex to SRC control patients. For the purpose of this study, PCS patients were those experiencing persistent symptoms at 3 months after an SRC; whereas, control patients were those with documented resolution of symptoms within 3 weeks of an SRC. Morgan \textit{et al} (2015) found that, in this age- and sex-matched case-control study risk for development of PCS was higher in those with a personal and/or family history of mood disorders, other psychiatric illness, and migraine\textsuperscript{7}.

Foley, \textit{et al} (2014) analyzed studies that looked at young age as a modifying factor in sport-related concussion outcome\textsuperscript{8}. They found, based on
multiple empirical studies that younger athletes may take longer to recover from a sports-related concussion (SRC) than their older peers. However, the studies did not indicate that younger athletes were at more risk for prolonged recovery. Although, young age has been shown to be modifying factor in concussion recovery, this study found that, the difference in recovery time was relatively small (a few days) and young age did not predict prolonged recovery.

Lee et al (2013) looked at how age affects symptom recovery after sport-related concussion in high school and collegiate athletes and found that there was no statistically significant difference in symptom presence, symptom severity, and total symptoms between the age groups at baseline or at post-concussion testing. There was no statistically significant difference in return to baseline symptom scores between the age groups.

3. Role of neuroimaging

Numerous neuroimaging studies using advanced dynamic techniques have in recent years shown white matter, neurovascular and neurometabolic abnormalities in athletes who sustained sport related concussions. Bazarian, et al (2014) reported on persistent, long-term white matter changes following sport-related head injuries among college athletes in the United States. Prospective, observational study of college football players was done using diffusion tensor imaging. All subjects underwent diffusion tensor imaging (DTI), physiologic, cognitive, and balance testing at pre-season (Time 1), post-season (Time 2), and after 6-months of no-contact rest (Time 3). Head impact measures were recorded using helmet-mounted accelerometers. Compared to controls, athletes experienced greater changes in fraction anisotropy (FA) and mean diffusivity (MD) from Time 1 to 2 as well as Time 1 to 3; most differences at Time 2 persisted to Time 3.

Dettwiler, et al (2014) also reported on persistent difference in patterns of brain activation after sport-related concussion using functional magnetic resonance imaging (fMRI). Their findings suggest that functional brain activation differences persist at 2 months after following concussion, and recovery of performance on a standard working memory task is comparable to normal controls and normalization of clinical and neuropsychological test results. These results might indicate a delay between neural and behaviorally assessed recovery after support related concussion.

Putukian, et al (2014) reported on long-term changes in white matter following sport-related concussion. They used diffusion tensor imaging (DTI) to assess white matter (WM) fiber tract integrity within 2 days, 2 weeks, and 2 months of concussive injury. Investigators found significantly increased radial diffusivity (RD) in athletes who sustained concussion at 2 days, when compared to the 2-week postinjury time point. At the same time fractional anisotropy (FA) was decreased at 2 days and at 2 months postinjury, when compared to healthy controls. At 2 weeks postinjury, no statistical differences between concussed and control athletes were found with regard to either RD or FA. These results support the hypothesis of increased RD and reduced FA within 72 h postinjury, followed by recovery that may extend beyond 2 weeks. RD appears to be a sensitive measure of concussive injury.

4. Concussion prevention and education programs

As part of prevention and education efforts for concussion, many programs have been developed in the United States; examples of some of them are shown here. Different programs are designed for athletes, their parents, coaches, and physicians. A review by Williamson, and colleagues of these programs note that formal educational programs are effective. Players who have received concussion education are twice as likely to report concussion-type symptoms to their coaches compared with student athletes who have not had such training. College athletes who receive concussion education at the beginning of the season demonstrate increased concussion awareness at the end of the season as a result of this training.

An important aspect of concussion prevention in the United States in recent years is the development of laws that require mandatory education, reporting and medical evaluation and clearance of athletes with concussion. This type of action was prompted by severe head injury of a young athlete, Zackery Lystedt, in the state of Washington. Now all states have some form of law that address sport related head injuries in young athletes.
Cardiovascular screening in young athletes

The incidence of sudden cardiac death or sudden cardiac arrest reported in the United States varies depending on the activity as shown which is higher in US military (1 in 9,000) and low in US marathon racers (1 in 184,000) \(^{13}\). Currently in the United States, use of electrocardiogram (ECG) as part of routine cardiovascular screening is not recommended and is a subject of debate \(^{13-18}\).

The 12-lead ECG obtained at rest on a nontraining day has been considered for screening based on the Italian experience showing marked decrease in sudden cardiac death (SCD) rates after making ECG part of standard screening \(^{18}\). The International Olympic Committee and the European Sports Council require an ECG before sports participation. Since 1973, in Japan all first, seventh, and tenth grade students routinely get a screening ECG. An ECG is found to be abnormal in 90% of patients with hypertrophic cardiomyopathy (HCM) \(^{13-18}\). Other high risk conditions for sudden cardiac death detectable by ECG include arrhythmogenic right ventricular cardiomyopathy (ARVC), ion channelopathies, dilated cardiomyopathy, and Wolff-Parkinson-White syndrome (WPW) \(^{13} 15 18\).

The 2010 European Sports Council (ESC) guidelines and the use of Seattle criteria for ECG interpretation in athletes provide support for including resting 12-lead ECG in screening athletes for SCD \(^{13} 14 18\). However, differences remain in the recommendations between the American and European cardiology guidelines on whether to use the ECG alone or in conjunction with a standardized history and physical examination before sport participation or heightened physical activity.

Studies in the United States have shown improved cost efficiencies when applying the new ECG criteria provided by the 2010 ESC studies. Studies at several large American colleges have used ECG screening along with echocardiogram (ECHO) for those with abnormal ECG screens \(^{18}\). Physicians with appropriate training across specialties could accurately detect abnormal versus normal ECG finding when provided standardized ECG criteria \(^{13-14}\).

One should first consider which ECG criteria to use. Salient cost factors for different groups or types of ECG screen testing protocols should be considered \(^{18}\). In addition to the cost of doing an ECG as a screen, the potential for additional evaluation and patient and family anxiety from false positive findings on ECG should be considered before obtaining an ECG \(^{18}\).

Although it is not a common practice in the United States to include an ECG in cardiovascular screening of young athletes at present, there is increasing support for use of as part of screening of athletes. A key consideration when using the ECG in athletes is the appropriate interpretation of the ECG findings. Many changes seen in ECG in athletes are result of effect on the heart from exercise training and are considered normal. These changes must be differentiated from truly abnormal findings \(^{13-15}\).

Sport and neurodevelopment of the child and adolescent

Over the past 2-3 decades there is an increasing trend for children to start sport as early 5 years of age. The intensity of activity has also increased. There is emphasis on specializing in a single sport. With such a trend studies have shown detrimental effects on child’s psychosocial and emotional development from stress of participation and expectation to excel in sports \(^{19} 20\). Also, studies have shown increased physical trauma at young age. One example is injuries to the anterior cruciate ligament in young athletes; also what we call overuse injuries in the young have increased. So the question often arises as to when is a child ready to engage in sport or what we call developmental readiness for sport participation \(^{19} 20\).

Developmental readiness for sport participation by young children depends on multiple factors \(^{19} 20\). These include the context within which sport participation occurs - just for fun or competition; the sociocultural environment - is this something a child wants or parents want, what is the importance of sport participation for the child or the parent? Also how do parents view sport participation by their child? On the other hand genetic factors may also play a role.

Sports readiness refers to the stage at which the child has reached the necessary maturity to learn a given sport- related task \(^{19} 20\). In other words, it results from a process in which the child acquires
the required motor, physical, cognitive, social, and adaptive abilities and is ready to meet the demands of a given sport. Readiness to play and to compete is influenced by biologic, physiologic, psychosocial, and environmental factors.

Participation in sports requires that the child be able to coordinate certain motor, cognitive, and physiologic functions, such as movements of the extremities, breathing, thinking, balancing, and many more. The ability to coordinate different actions is influenced by a child’s level of thought processing ability, thinking speed, agility, flexibility, strength, and endurance.

Some researchers have proposed that certain critical periods occur, during which sport skills are learned best. On the other hand, it is not necessary that children learn such skills during these periods. Because multiple factors influence readiness and determine the varying rates of growth and development, athletic talent cannot be reliably identified in children, nor can athletic excellence in children be predicted. In general, children younger than age 6 do not have the ability to compare their own abilities with those of others; nor do they have the cognitive maturity to understand the competitive nature of sport before age 9. The ability to fully understand the complex tasks of a given sport may not be fully developed until a child is 12 years of age.

Conclusion

In recent years in pediatric sports medicine practice many areas have been explored because of increased participation of young children and adolescents in more intense sports. This short update has explored some current issues in sport-related concussions, cardiovascular screening of young athletes and neurodevelopment and sport participation. Sport-related concussion in young athletes can have significant long term neurocognitive implications and prevention and management guidelines should be followed appropriately. In the United States cardiovascular screening of young athletes is largely based on history and physical examination; however, there is an increased attention and practice to include electrocardiogram as part of the screening process. A trend in intense and specialized sport participation among young children has physical and psychological implications for children. Increased overuse injuries have been noted and some studies indicate adverse psychosocial impact in children because of such intense sport participation at very young age. These issues will continue to need more research and attention in coming years.

References

1) Noble JM, Hesdorffer DC: Sport-related concussions: a review of epidemiology, challenges in diagnosis, and potential risk factors. Neuropsychol Rev, 2013; 23: 273-284.
2) Kamitani T, Nimurs Y, Nagahiro S, Miyazaki S, Tomatsu T: Catastrophic head and neck injuries in judo players in Japan from 2003 to 2010. Am J Sports Med, 2013; 41: 1915–1921.
3) McCroy P, Meeuwisse WH, Aubry M, et al: Concensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. Br J Sports Med, 2013; 47: 250–258.
4) West TA, Marion DW: Current recommendations for the diagnosis and treatment of concussion in sport: a comparison of three new guidelines. J Neurotrauma, 2014; 31: 159–168.
5) Halstead ME, Walter KD, AAP: Clinical report: sport-related concussion in children and adolescents. Pediatrics, 2010; 126: 597–615.
6) Lee YM, Odom M, Zuckerman SL, Solomon GS, Sills AK: Does age affect symptom recovery after sports-related concussion? A study of high school and college athletes. J Neurosurg Pediatr, 2013; 12: 537–544.
7) Morgan CD, Zuckerman SL, Lee YM, et al: Predictors of postconcussion syndrome after sports-related concussion in young athletes: a matched case-control study. J Neurosurg Pediatric, 2015; 15: 589–598.
8) Foley C, Gregory A, Solomon G: Young age as a modifying factor in sports concussion management: What is the evidence? Curr Sports Med Rep, 2014; 13: 390–394.
9) Putukian M, Echemendia RJ, Osherson DN, Dettwiler A: A longitudinal diffusion tensor imaging study assessing white matter fiber tracts after sports-related concussions. J Neurotrauma, 2014; 31: 1860–1871.
10) Dettwiler A, Murugavel M, Putukian M, Cubon V, Furtado J, Osherson D: Persistent differences in patterns of brain activation after sports-related concussion: a longitudinal functional magnetic resonance study. J Neurotrauma, 2014; 31: 180–188.
11) Bazarian JJ, Zhu T, Zhong J, et al: Persistent, long-term cerebral white matter changes after sports-related repetitive head impacts. PLOS One, 2014; 9: e94734.
12) Willimason RW, Gerhardstein D, Cardenas J, Michael DB, Theodore N, Rosseau N: Concussion 101: the current, state of concussion education programs. Neurosurgery, 2014; 75 (Supple 4): S131–S135.
13) Schmied C, Borjesson M: Sudden cardiac death in athletes. J Intern Med, 2014; 275: 93–103.
14) Drezner JA, Ackerman MJ, Anderson J, et al: Electrocardiographic interpretation in athletes: the ‘Seattle Criteria’. Br J Sports Med, 2013; 47: 122–124.
15) Mortazavi M: Sudden cardiac death in young athletes. Adv Pediatr, 2013; 60: 201–215.
16) Chaitman BR: An electrocardiogram should not be included in routine preparticipation screening of young athletes. Circulation, 2007; 116: 2610–2615.
17) Meyerberg RJ, Vetter VL: Electrocardiograms should be included in preparticipation screening of athletes. Circulation, 2007; 116: 2616–2626.
18) Patel DR, Luckstead EF Jr: Update on cardiovascular screening: can we prevent sudden cardiac death in adolescent athletes? Adolesc Med State Art Rev, 2013; 24: 225–241.
19) Patel DR, Greydanus DE, Pratt HD: Youth sports: more than sprains and strains. Contemporary Pediatrics, 2001; 18: 45–74.
20) Patel DR, Pratt HD, Greydanus DE: Pediatric neurodevelopment and sports participation. Pediatr Clin North Am, 2002; 49: 505–531.