

Evaluation and management of sport-related concussions in adolescent athletes

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Abstract: Sport-related concussions in young athletes are common, generally under reported and often go unrecognized. Concussion in sport may result either from a direct impact to the head or from indirect forces transmitted to the brain from impact elsewhere on the body. Concussions may also result from sudden acceleration, deceleration or rotational forces to the brain. The key features of concussion include confusion, impaired memory and reduced speed of information processing. Recovery may occur from a few days to several weeks or months. Both physical and cognitive rests are recommended for recovery. Long-term cognitive and behavioral complications are a concern. Preventive strategies include education, modification of sport rules, use of equipment such as headgears, face masks and mouth guards, and neck muscle training. Evidence is limited to support effectiveness of these preventive measures with the exception of rule modification in some sports. Laws have been enacted that require medical evaluation and clearance prior to return to play; however, evidence thus far does not show that laws have been effective in reducing the incidence of concussions in sport. More research is needed in all areas of preventive measures. Sports participation is a complex personal decision on the part of adolescent and his or her family. They should be provided with all information on inherent risks so that they can make an informed decision.

Keywords: Concussion; Zurich guidelines; neuropsychological testing; sport concussion assessment tool

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Introduction

Sport participation by adolescent athletes is an important developmental milestone and should be encouraged for its well established benefits. However, it should be recognized that sport participation carries inherent risk of injury. Our efforts should therefore be directed to mitigate such risks of injury, rather than trying to completely eliminate such risks. Sport-related concussions in youth are common and can have significant long term adverse impact on athlete's life. This paper reviews the definition, epidemiology, and clinical aspects of sport-related concussions based on current published guidelines. Preventive strategies are evaluated

within the context of organized youth sports in the United States.

A number of preventive measures and strategies have been developed and tried with variable effectiveness. Primary prevention of concussion is an elusive concept because in most sports, every time an athlete is in practice or game there is a risk for concussion. The only sure way of not having a sport-related concussion is not to participate in sports with risk for concussion. Since not participating sports is not such a viable option, our efforts are at best directed at secondary and tertiary prevention of concussion and its complications.

Definition

Concussion in sports has been defined variably in different guidelines; however, some elements are common across all definitions (1-6). A well-established criterion for concussion is a trauma-induced alteration in mental status. Loss of consciousness is not considered essential to define a concussion. The main features considered essential and seen in most athletes who have concussion include confusion, some level of impaired memory, and reduced speed of information processing. The onset of these symptoms may occur soon after the brain injury or may take several minutes. Currently a widely used definition of sport-related concussion is that proposed by the Zurich consensus statement on sport concussions (1). This definition, which includes certain common clinical, pathological and biomechanical characteristics of concussion, is as follows:

- ❖ Concussion may be caused by a direct blow to the head, face, neck or elsewhere on the body with “impulsive” force transmitted to the head;
- ❖ Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously;
- ❖ Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury;
- ❖ Concussion may result in a graded set of clinical syndromes that may or may not involve loss of consciousness;
- ❖ Resolution of the clinical and cognitive symptoms typically follows a sequential course; however, in a small percentage of cases, post-concussive symptoms may be prolonged;
- ❖ No abnormality on standard structural neuroimaging studies is seen in concussion.

Special considerations in adolescents

In adolescent athletes, evaluation and management of concussions should take into account the developmental stage of the adolescent (7-9). The cognitive, physical and psychosocial developmental stage has direct implications for the evaluation, management and developing prevention strategies for concussions in adolescents (9-12). Early adolescent (generally 11–14 y) development is characterized by concrete thinking, concern about physical changes in the body, and physical appearance. During this time the adolescent may not be able to fully understand the

significance of short-term and long-term effects or complications of concussions. Adolescents at this stage may not consider it important to report head impacts or symptoms. They also are less likely to adhere to a recommended treatment plan. During evaluation, a more direct questioning is appropriate.

Middle adolescent years (generally 14–16 y) are a time for taking risks and experimenting. There is more independent behavior, and a sense of invulnerability. Peer pressure and peer acceptance are very important. Because of a sense of invulnerability, the adolescent may continue to participate in sports against medical advice. When the adolescent is not able to continue to return to sport for a period of few days or more he or she may find it difficult to cope and may find it hard to adjust. During middle adolescent years social comparison and peer recognition play a vital role and sport participation is highly valued by adolescents. This should be taken into account when treating adolescent at this stage of development.

Late adolescent years (generally 17–19 y) are characterized by development of abstract thinking. The adolescent is now able to understand the risks of concussions much better. He or she is more likely to seek and follow medical advice regarding head injury and its complications.

Epidemiology

Most reports on the incidence of sport-related concussions in adolescents acknowledge that in general there is a significant level of under recognition and under reporting of concussions. Depending up on the immediate importance and significance of continued participation in the practice or game, the adolescent, and in many instances the sport officials many not report the concussion. The adolescent may be concerned that he or she will be pulled out the game. Because symptoms of concussion are often subtle and non-specific, they either go unrecognized or their significance may be minimized.

According to the CDC, in the United States, approximately 300,000 head injuries are reported annually in high-school sports; 90% of these are concussions (6,13). The estimated incidence is 0.14–3.66 concussions per 100 player seasons (14). This translates into 3% to 5% of all sport related injuries in high school athletes (14,15). The High School Reporting Information Online and National Collegiate Athletic Association Injury Surveillance data show that concussions account for 8.9% (n=396) of all

high school sport injuries, and 5.8% (n=482) account for all injuries in college sports (13). In high school athletes, American football accounts for the highest number of reported concussions (16). After American football, the reported incidence of concussion in high school athletes in decreasing order is as follows: ice hockey, soccer, wrestling, basketball, field hockey, baseball and softball (16-18).

Mechanism and pathophysiology

Concussion occurs following a direct collision of the head with another unyielding surface. In contact-collision sports, direct impact to the head can occur from a collision with another player, a ball, or a hard surface. In addition to direct hit to the head, concussion can also occur by forces transmitted to the brain from an impact to the face, jaw and neck regions. Significant collision between players without direct impact to the head can also result in concussion from forces transmitted to the brain from other parts of the body.

It is important to recognize that concussion can also occur without any direct impact to the head or other parts of the body. During most sports there is a significant amount of sudden, short or long duration running, pivoting, jumping, and stopping. These activities generate significant acceleration, deceleration and rotational forces imparted to the body as a whole as well as to the brain (1,5,10). Studies have shown that such acceleration, deceleration or rotational forces can also result in concussions (1,5,10). This information has direct implications for the evaluation, treatment and prevention of concussions. Although it is easy to understand that direct hit to the head can result in brain injury, it is often difficult for young athletes, parents, and coaches to understand that concussion can occur without direct hit to the head. The athlete may think that his or her head did not hit another object and therefore it is not likely that a brain injury occurred.

Concussion is characterized by injury at neuronal cell level (4,5,12). There is an injury to the cell wall that results in increased exchange of ions into and out of the cell. Potassium from inside the cell moves out at a greater rate; this triggers the release of excitatory amino acids by activation of the calcium-dependent pathway. The key neuronal excitatory amino acid is glutamate. Increased concentration of potassium outside of the cell leads to depolarization of the cell wall. Depolarization of the cell wall suppresses neuronal cell activity. This in turn triggers activation of the sodium-potassium pump to restore the balance of ions inside and outside of the cell.

All this increased activity at the cellular level increases the metabolism and uses up more glucose and energy. The increased need for glucose is met by breakdown of its storage form, glycogen. To meet the increased need for glucose and energy, there is a need for an increase in the blood flow to the brain. However, because of the injury to the brain cells from concussion, blood flow is decreased. This mismatch between the energy and metabolic demand can last from 1 to 10 days following concussion in most cases. During this time the brain remains highly susceptible to further injury.

Clinical aspects

Adolescent athletes can present for medical attention during the practice or game to the athletic trainer or other healthcare provider on site providing medical coverage for the event. They may also be seen by their own doctor later for an evaluation, follow-up or clearance for return to play visit. In many cases, the symptoms or signs of concussion may resolve only to recur later. On the other hand, signs and symptoms of concussion may first appear several days or weeks following the concussion. Many student athletes present to their clinician for the first time seeking medical attention when they notice deterioration in their academic functioning or change in mood or behavior.

In the clinical evaluation of the adolescent athlete for concussion, there is usually a history of impact to the head or other part of the body from collision with another player, being hit in the head by a ball or other object such as a puck or bat, or a fall to the ground. It is important to note that concussion can occur without direct hit to the head or body. In some cases, other players or someone else at the practice or game may observe that the athlete is not behaving appropriately or not able to follow the directions. This should raise suspicion of concussion. Most commonly the athlete with concussion is confused, disoriented and not able to follow simple directions within the context of the game.

A number of signs and symptoms associated with concussion have been described. Most of these are non-specific and may also be seen in other medical conditions; therefore, it is important to relate the onset of signs and symptoms to the head injury (4,11,19,20). Some signs and symptoms may appear soon after the concussion, while other may appear over a period of several days to weeks. The main signs and symptoms of concussion are as follows (1,5,10,21):

- ❖ Changes in mental status: impaired recall of events, confusion, disorientation as to time, place and person; increased distractibility; drowsiness; feeling foggy; impaired level of consciousness; change in play behaviors; deterioration in concentration and attention; slow speech; difficulty in following directions; seeing “stars” or “flashes”;
- ❖ Changes in behavior or psychosomatic: emotional lability; irritability; changes in personality; anxiety; nervousness; feeling sad; depression; decreased frustration tolerance;
- ❖ Physical: poor balance; changes in vision; double vision; deterioration in sport performance; dizziness; undue fatigue; headache; lightheadedness; nausea; vomiting; poor coordination; ringing in ears; vacant look; rarely seizures.

There is no one or combination of many signs or symptoms that is diagnostic of concussion. It is helpful to establish a contemporaneous relationship between the head injury and onset of signs and symptoms. Various concussion guidelines provide signs and symptoms check lists that can be used by clinicians to document their evaluation in a consistent manner. A widely used such a tool is called Sport Concussion Assessment Tool 3 (SCAT-3).

In addition to the history of injury and onset of signs and symptoms, the clinician should perform a complete neurological examination and assess cognitive functioning. Cognitive function can be assessed clinically or by formal standardized cognitive tests (1,5,10,22). To interpret the results of cognitive assessment, it is useful to have a pre-injury cognitive profile of the athlete so that it can be compared with the post-injury profile. The conventional (“paper and pencil”) cognitive tests have not been specifically constructed or validated for sport-related concussion evaluation, need special expertise from psychologist to administer and interpret the results, take long time, and are expensive.

Over the past decade, several computer based short cognitive tests have been developed that are specifically designed and validated for sport related concussion assessment (23). Examples of these types of test platforms include: Automated Neuropsychological Assessment Metrics, CogSport, Concussion Resolution Index, Immediate Measurement of Performance and Cognitive Testing (IMPACT), and Standardized Assessment of Concussion (23). Major cognitive functions assessed by neuropsychological (NP) testing include: amnesia after concussion; attention span; mental flexibility; motor

coordination; speed of information processing; orientation in time, place and person; reaction time; visual scanning; and verbal memory (12,23).

Computer based NP testing has been now widely used at all levels of sports—professional, collegiate, and high-school (23). Athletes who participate in contact sports are given these tests prior to sport season to obtain their pre-injury or baseline NP profile, which can be compared later post-injury. Computer based NP testing has been found to be clinically useful, cost-effective and easy to administer and interpret. Such NP testing can be used to monitor the progress of athletes with concussion during recovery. In combination with clinical evaluation, NP test results provide criteria in return to play decisions.

Neuroimaging is not recommended as a routine test for evaluation of concussion (24). Neuroimaging is indicated based on clinical signs and symptoms, progression of symptoms, failure of resolution as expected (generally more than 2 weeks) or loss of consciousness for more than 1 minute (1,4,12). Computerized tomography and magnetic resonance imaging are primary modalities used for neuroimaging. Special types of neuroimaging techniques are used to delineate injury to brain structures as well as to assess metabolic function of brain (24). Diffusion tensor imaging is one technique used to specifically assess damage to white matter tracts (24). Function of brain cells can be assessed by use of functional magnetic resonance imaging and single photon emission tomography (24).

Management

Management of young athletes with concussion has evolved rapidly over the past decade resulting the development of different guidelines that describe a fundamentally similar approach for the treatment of concussions (1-4,19-22). Concussion severity grading based on various criteria such as the presence or absence and duration of loss of consciousness, confusion and memory are no longer used or found clinically useful (1,5,10). Loss of consciousness is not essential to define concussion (1). It is recognized that an individual athlete may follow a variable course from injury to recovery. Therefore, a step by step plan for athletes to return to play is preferred. There is no fixed time period of required rest (25-29). Return to play decision is based more on clinical recovery rather than pre-determined number of days of rest (25-29). Studies have shown that most athletes fully recover from concussion from 2–3 week to 1–3 months (1). A very small subset of athletes continues to have persistent signs and symptoms beyond

3 months (1,5). Generally, it is a common practice to remove the athlete from sport participation following a concussion for 7–10 days before beginning the return to play protocol (1,25–27).

The Zurich concussion guidelines recommend the following stepwise process for athletes with concussion:

- (I) No activity, complete physical and cognitive rest;
- (II) Light aerobic exercise (walking, stationary cycling keeping intensity more than 70% maximum predicted heart rate, and no resistance exercise);
- (III) Sport specific exercises (skating in hockey, running in soccer);
- (IV) Non-contact training drills (progression to more complex training drills, for example, passing drills in football; may also start resistance training);
- (V) Full contact practice following medical evaluation and clearance;
- (VI) Return to unrestricted sport participation.

During the implementation of the step wise protocol, the athlete should be symptom free at current level of the protocol before proceeding to the next step. If symptoms recur, the athlete should rest for 24 hours and try the same step again. Before returning to full sport participation, the athlete should be completely free of any signs or symptoms, and must have a normal neurological examination.

The concept of cognitive rest is important to communicate to the athlete and his or her parents (4,30,31). In addition to physical rest—no sport participation, no similar level of other physical activity—the athlete should not engage in other activities such as, texting or watching television. He or she should not be expected to keep up with school work (4,30,31). School work needs to be appropriately modified. The athlete should gradually assume increased level of cognitive work, such as school assignments, and homework. School should be informed of athlete's cognitive limitations during the recovery phase and an individualized educational plan may need to be implemented by the school. During this recovery phase the school may need to consider educational accommodations for the athlete.

Some of the educational accommodations that can be applied are as follows:

- ❖ Allow more time to complete class work and tests;
- ❖ Reduce the number of homework assignments and school work assignments;
- ❖ Provide more detailed written instructions to the student regarding work assignments;
- ❖ Provide assistance of a note-taker;

- ❖ Simplify complex tasks by breaking them into simple steps.

When managing concussion and considering return to sports the question of how many concussions are too many often comes up. There is no definite answer to this question. It is generally agreed that repeated concussions have long-term cumulative and persistent adverse effect on brain function. Such effects are relatively greater for concussions that occur at successively shorter intervals.

Outcome and quality of life

Recovery period from concussion is variable; however, most adolescent athletes recover fully within 7–10 days after concussion (1,2,5). A small percentage of athletes may take up to 1–3 months before full recovery (1,5). Studies have shown that approximately 30% of high school and collegiate athletes are able to return to sports within 1 day and the remaining 70% in 4 days (1,2,5,12). For adolescent athletes, same day return to sports is not recommended regardless of full clinical recovery (4). It is important to recognize that some emotional or behavioral symptoms may persist for weeks to months even after full physical and cognitive recovery from concussion (32–35).

Adolescents tend to have a relatively prolonged recovery phase compared to adults (4,35). Adolescent athletes who have sustained one concussion are also more likely to have another concussion. Persistent cognitive deficits may result in lifelong academic and psychosocial difficulties.

A condition called second impact syndrome has been described in adolescent male athletes who return to sports prematurely before full recovery from previous concussion (5,12). This is believed to be due to another brain injury during the vulnerable time period following a concussion. Second impact syndrome is rare, but rapidly progressive with a high level of fatality. This is one reason for not allowing the athlete to return to sports before full recovery.

Discussion

Limitations of current guidelines

Current concussion practice guidelines at best represent expert opinion and consensus and have several limitations (36). The definition of concussion used in most guidelines is based on a constellation of symptoms which are nonspecific. These symptoms may be seen in many other medical conditions and cannot be attributed with any level of certainty to result solely

from concussion. There are no objective laboratories or imaging studies to make a definitive diagnosis of concussion. The guidelines therefore lack specificity and likely result in over diagnosis of concussion. On the other hand, other medical conditions with similar symptoms may be missed. The stepwise management approach recommended in most guidelines has not been validated by any rigorous study. Many individuals have baseline symptoms that precede the injury and therefore may not allow appropriate application of the concept of “asymptomatic” state post-injury (37). The guidelines also do not take into consideration the potential variability related to athletes age or gender. The return-to-play step wise protocol proposed in most guidelines is based on clinical judgment and self-reported symptoms and not based on studies that are validated in athletes.

Gaps in knowledge

The exact incidence of sport-related concussion in adolescents is not known. Problems include methodological difference in data collection and reporting as well as underreporting. There are no systematic surveillance systems to collect data in youth sports concussions and the data collected do not include sufficient information, such as level of competition, even type, or the mechanism of injury. Studies on short-term and long-term neurocognitive consequences of concussion suffer from small sample sizes and methodological difference. Imaging studies on athletes who suffered concussion do not provide consistent findings. There is a lack of information on impact of repetitive concussion over lifespan. With the exception of few sports, we do not know what rule changes are effective in preventing concussion across many other sports. Studies on protective equipment are mostly limited to animal models and laboratory settings rather than in real sport play, especially in youth sports.

Conclusions

More resource and effort should be redirected from simple knowledge-based education about concussion to developing programs that address the inherent culture of American youth sport that is conducive to concussion and other sport related injuries. There is a need for a cultural paradigm shift from winning in sport at all costs to sports for fun and sport being adult organized and adult governed activity to a more youth directed and youth organized spontaneous activity.

There should be more cohesive efforts in modifying

rules of the sport and more research across sports to assess their effectiveness in this area and more robust enforcement of rules of the sport. There should be a more rigorous oversight of the industry that claims their devices prevent concussions. Such claims should be based on evidence supported by robust research. With the use of any injury protective device in sport, the concept of risk compensation has been studied by several investigators. This is based on the theory that everyone has an acceptable level of risk. If the level of risk is reduced from the individual's acceptable risk, there is a tendency for the individual to take a higher risk and reach an equilibrium. This principle is also applicable to any other risk reduction strategy.

Prevention and management of sport related concussions should be within the purview of healthcare professionals and scientists and not legislatures. Law and public policy debate should focus more on the culture of youth sport in America in general rather than targeting (and hoping to prevent) narrowly on laws to prevent concussions.

Decision to participate in sport is a very personal and complex process for the young athlete and his or her family to consider. They should be provided with all the information and resources available for them to make an informed decision. Without addressing the broader issues of sport culture, and role of sport in the lives of children and adolescents, we are not likely to succeed in preventing sport related concussions or other injuries in youth.

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Footnote

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