Concussions and Brain Injuries in Youth Sports

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After Zackery Lystedt's brain injury, "he couldn't speak for nine months," his father said. Thirteen months later, "he could move his left arm a little; it took two years to get rid of the feeding tube and four years before he could move his right leg purposefully." Zackery had suffered a concussion during a high school football game in 2006, but "was twice returned to play and collapsed 60 seconds after the game was over."[1] The school district settled a lawsuit for $14.6 million.[2]

About 1.6–3.8 million sports-related concussions occur every year,[3] and a recent study found that "182,000 football players may sustain at least one concussion annually in youth (99,000), high school (79,640), and NCAA football programs (3,905)," or about 1 in 30 youth players and 1 in 14 high school players.[4] Symptoms may appear mild but the injury can lead to life-long problems with physical function, concentration, memory, behavior, and emotion. Tragically, among high-school football athletes there were eight fatalities directly related to brain injuries in the 2013 season.[5]

At present, all fifty states have sports concussion laws modeled after the 2009 law in Washington that resulted from Zackery Lystedt's tragedy. Every law includes three components: education about the nature and risk of concussion and head injury for coaches, athletes, and parents/guardians; removal from play after a suspected concussion; and return to play with the approval of a trained and licensed practitioner.[6]

Definition of Concussion

The 4th International Conference on Concussion in Sport in 2012 (ICCS) defined a concussion as a complex process induced by biomechanical trauma, with the following common clinical, pathologic, and biomechanical features:[7]

1. Concussion typically causes short-lived impairment of neurological function that resolves spontaneously, but symptoms and signs may evolve over minutes to hours.
2. Concussion may cause neuropathology, but the symptoms reflect functional rather than structural changes, so standard neuro-imaging is normal.
3. The graded set of clinical symptoms may or may not involve loss of consciousness. Symptoms typically resolve in a sequential manner, but may be prolonged in some cases.

Symptoms of a Concussion

Symptoms after a concussion can be somatic, cognitive, or emotional – in varying combinations. The injured athlete may feel "dazed" or "stunned," and may experience headaches, nausea, vomiting, impaired balance, visual problems, photosensitivity, phonosensitivity, and fatigue. Cognitive problems include mental "fogginess," slow information processing, slow speech, slow reaction times, impaired concentration, amnesia, and memory deficits. There may be emotional changes such as lability, irritability, anxiety, and sadness. Sleep patterns may also be affected, due to insomnia or drowsiness.

Warning signs of a more severe injury – intracranial bleeding, edema and impending herniation – include a severe headache, altered mental status, slurred speech, vomiting, a skull fracture, or a focal neurologic deficit such as diplopia. In these situations, prompt emergency evaluation is necessary.

Pathophysiology of Concussion

Trauma displaces the brain within the skull; compresses neural tissue; accelerates, decelerates, and rotates the brain within the hard casing of the skull; and causes a coup as well as a contre-coup injury. Cortical pathways are disrupted, as seen on diffusion tensor tractography, especially with frontal lobe connections;[8] damage to the brainstem's reticular activating pathways alters consciousness. Pathologic changes include neuronal swelling and axonal disruption. Biochemical abnormalities include a sterile inflammatory response and metabolic changes. Injury to the young brain may also be related to elasticity of the skull sutures and the presence of vulnerable unmyelinated fibers in white matter tracts. Diffuse axonal injury involves mechanical disruption of the axon's cytoskeleton and axonal transport as well as axonal swelling, proteolysis, disconnection, and reorganization. Disruption of neural membranes affects ion channels, leading to potassium efflux, the release of glutamate, higher energy (ATP and glucose) consumption, increased lactate, increased Na-K pump activity, suppressed nerve activity, decreased blood flow, a hypometabolic state, and eventual cell death. Mitochondrial dysfunction and demyelination are also involved in diffuse axonal injury.[9]

Immediate Evaluation of a Concussion

If there are <u>any</u> symptoms of a concussion, the ICCS guidelines are clear:[7]

A. The player should be evaluated and treated by a physician or other licensed healthcare provider and a cervical spine injury should be excluded.

B. If no healthcare provider is available, the player should be removed from the field and promptly sent to a physician.

C. Once the first aid issues are addressed, the concussive injury should be assessed with the SCAT3 or similar tools.

D. The player should be closely monitored for the initial few hours following injury.

E. A player with diagnosed concussion should not return to play on the day of injury.

Assessments after a Concussion

The Standardized Assessment of Concussion (SAC) is an effective, 6-minute tool for assessing orientation, concentration, immediate memory, and delayed recall. Laypersons may use the SAC at athletic events to identify a concussion, and the test has a sensitivity up to 94% and specificity up to 91%.[10,11] A modified version for use in emergency departments has also been developed, with the addition of a Graded Symptom Checklist (headache, nausea, vomiting, blurred vision, etc.) and Neurologic Screening (amnesia, strength, sensation, coordination).[12]

Concussion in Younger Athletes

Although most (80–90%) concussions resolve within 7– 10 days, the recovery process can be longer and more complicated in children and adolescents.[13] Furthermore, younger athletes have a higher risk of severe symptoms and cognitive decline.[14] This age difference in recovery and prognosis is probably related to the ongoing development of a child's brain. The primary senses, motor skills, and language are well developed by age ten. Frontal lobe maturation, however, goes on during the teenage years and even into the early 20s; these brain functions include abstraction, reasoning, judgment, insight, and emotional control.[9] Consequently, achieving optimal recovery is critical for helping students with concussions.

Due to the more complex recovery process in young athletes, they need protection when they are most vulnerable. Recurrent concussions are especially destructive to the brain and are more likely during the first ten days after a concussion or if the athlete has had a previous concussion.[11] We recommend waiting at least seven days until return to play, regardless of the nature of the injury, because the long-term risks far outweigh any short-term benefits of the sport.

A Model of Concussion Care

Sargent Rehabilitation Center has a Concussion Management Clinic with a team of rehabilitation professionals for evaluation and treatment of student athletes. After a medical evaluation by the athlete's primary physician, Sargent's team evaluates cognitive function (concentration, memory, executive function, etc.) as well as behavioral, emotional, and physical changes. With the community school team, a comprehensive survey of the student in the classroom and extra-curricular activities is performed. Concussion management includes short-term rehabilitation, school preparedness, and prevention of another concussion as well as monitoring and management of re-emergent symptoms.

The concussion clinic offers baseline/pre-season Immediate Post-concussion Assessment and Cognitive Testing (ImPACT) to school systems (**Figure 1**). This online test of attention span, memory, non-verbal problem solving, and reaction time is also used for follow-up evaluations in case of a brain injury. Among athletes with suspected concussions, the test was 91.4% sensitive and 69.1% specific. Notably, with athletes who denied symptoms but had a suspected concussion, ImPACT testing yielded 94.6% sensitivity and 97.3% specificity.[15] The NeuroCom SMART EquiTest CDP® is used by the clinic's therapists to assess and retrain balance mechanisms with visual biofeedback (**Figure 2**). This system uses a stable or unstable surface (with a dynamic force plate) in a static or dynamic visual environment. Computerized protocols such as the Sensory Organization Test (SOT) measure the ability to maintain equilibrium with changes in

Figure 1. Visual-perceptual testing with the ImPACT test

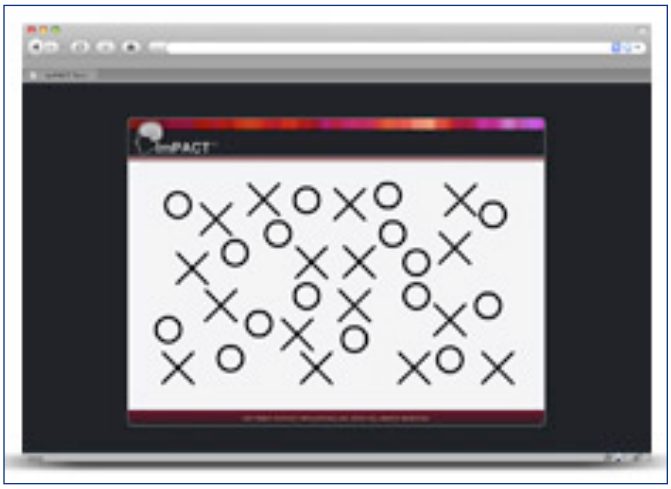
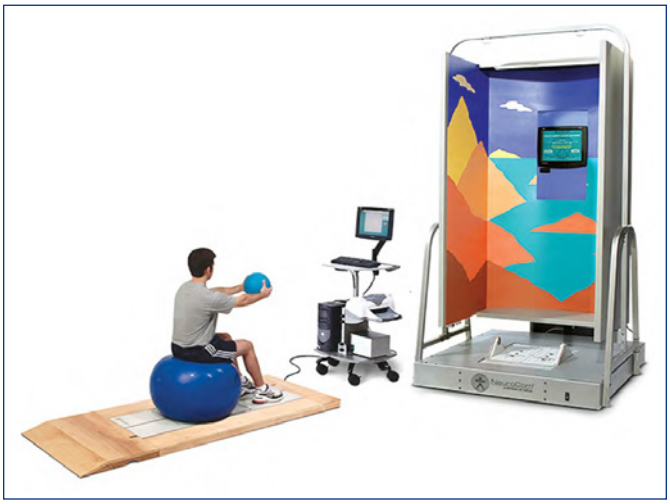


Figure 2. Balance testing with the NeuroCom SMART EquiTest CDP®



somatosensory or visual input or both. The SOT identifies concussions with a sensitivity of 48%–61% and specificity of 85%–90%.[16, 11] Combining the ImPACT and Neurocom tests yields even better sensitivity and specificity for concussions, as the two assessments encompass cognitive, cerebellar, and visual brain pathways. The clinical program at the Concussion Management Clinic is described in the following case report.

Case Report

A sixteen-year-old male named "John" suffered a concussion due to a head butt in a soccer game. Two weeks later, he obtained physician clearance to return to school and the soccer field, but had decreased cognitive and physical functioning: an awkward gait and difficulty with comprehending texts. On the fourth day of his return, he fell and could not remember if he hit his head. Three weeks after the soccer injury, John fell down the stairs in his house and was diagnosed with a second concussion. Subsequently he had memory problems and severe headaches.

Unable to attend school, John was referred to Sargent Center and the intake committee determined that he was appropriate for the Concussion Management Clinic. His evaluations were scheduled in short sessions to accommodate his headaches and associated fatigue. John was provided educational, speech, and physical therapy three days a week. His progress was closely monitored by Sargent's medical and nursing services. A coordinated plan of treatment and school management was developed by the concussion clinic and his school. The clinic staff also provided ongoing support to the family. After six weeks, John's balance issues had resolved and the concussion clinic and school teams coordinated a return to school, three days a week for two hours each day.

The school was trained to reinforce the rehabilitation strategies for John to improve his memory, attention, processing speed, and balance. Over the next month his school attendance increased to five 2-hour days. The concussion clinic staff and the school continued working on John's class instruction, learning strategies, and problem-solving. Four months after starting at the concussion clinic, he returned to school full-time. With educational accommodations, he successfully advanced to the next grade.

This case report describes a male soccer player, but girls are at especially high risk in this sport. A prospective study of female soccer players (ages 11-14) found 59 concussions during 43.7 thousand hours; a cumulative incidence of 13.0% per season; and a duration of concussion symptoms for an average of 9.4 days. About 30% of concussions were due to heading the ball. Longer recovery times occurred with the presence of light sensitivity, emotional lability, noise sensitivity, memory loss, nausea, and impaired concentration. Unfortunately, almost 60% of athletes kept playing in spite of their symptoms and only 44.1% sought medical attention.[17] (These data raise important questions about the necessity, value, and risks of heading the ball in youth soccer.)

Rhode Island School and Youth Programs Concussion Act & Education

This law (2010, 2014) requires the Departments of Education and of Health to work with the Rhode Island Interscholastic League to educate coaches, teachers, school nurses, youth athletes, and parents/guardians about concussion and head injury (C & HI).[18] To play sports after an injury, an information sheet must be signed by the athlete and the parent/guardian. All coaches, school nurses and volunteers must take a training course and an annual refresher on C & HI. Teachers and teachers' aides are strongly encouraged to complete a training course. School districts are encouraged to arrange baseline neuropsychological testing. Parents/guardians should receive information about C & HI before the season and should acknowledge receipt of that material. Any "youth athlete who is suspected of sustaining a concussion or head injury in a practice or game shall be removed from competition." The athlete "may not return to play until an evaluation by a licensed physician who may consult with an athletic trainer, all of whom shall be trained in the evaluation and management of concussions. The athlete must receive written clearance to return to play" from that licensed physician.

To help compliance with the RI Concussion Act, Sargent's Regional Resource Center offers conferences and workshops on health care, education, policy, and the law. The target audience includes families, physicians, nurses, coaches, athletic directors and trainers, teachers, rehabilitation specialists, psychologists, counselors, social workers and school administrators. Education does reduce injuries. In a recent study of education about injury prevention, some coaches was not educated, another group received the Heads Up Football coaching program (HUF), and a third was educated about the HUF and also given the Pop Warner Football (PW) guidelines to restrict contact during practice. Among football players (ages 11 to 15), the concussions during practice were much lower in the HUF + PW group (0.14/1,000 athlete exposures (AEs)) compared to the non-educated cohort (0.79/1000 AEs).[19]

Education about injury prevention is especially important in youth football. These athletes are vulnerable to the second-impact syndrome, in which the patient with a brain injury has ongoing symptoms – and then has another head injury. Forensic studies suggest that the second trauma worsens the initial damage, which predisposes the brain to a more intense pathophysiologic response and leads to diffuse cerebral edema, brainstem herniation, and death.[9]

Conclusion

Sports offer many benefits to students, but their well-being and cognitive, emotional, and behavioral potential should never be compromised. Zackery Lystedt's story is tragic, and there are thousands of other student athletes whose lives have been damaged by concussions to a less severe extent. Health care professionals have the responsibility to effectively and ethically manage the epidemic of youth sports concussions and brain injuries.[20]

Suppliers

ImPACT Test: https://www.impacttest.com/products/?The-ImPACT-Test-2

Neurocom: http://www.natus.com/documents/015368A_SMART_EquiTest_EN-US_lo-res.pdf

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