Concerns over the potential for long-term consequences after concussion injuries among participants in youth sports is triggering a wave of research, heightened media awareness, and a spate of new laws, rules, and regulations intended to protect the developing brain.

The number of concussion injuries reported among school-aged children—estimated to be responsible for five percent to 13 percent of all reported injuries in high-school athletes and the inciting cause for over 100,000 emergency department visits a year for school-aged children—is, for some, a cause for alarm. Yet, a lack of objective diagnostic criteria, the potential for underreporting, as well as a surge of new concussion diagnoses perhaps resulting from renewed vigilance, all confound to blur actual incidence data.

Concussions are acknowledged to be a subset of traumatic brain injury (TBI), and as such, a serious injury irrespective of age and regardless of whether occurring in or out of the sporting realm. However, the popularity of youth sports coupled with the potential for long-term implications of concussion injuries have raised the specter that adolescent and youth concussions constitute a more serious problem than similar injuries among adults.

FUNCTIONAL INJURY TO THE GROWING BRAIN

A growing body of literature is highlighting a biologic rationale for the notion that youth concussions portend a worse outcome compared with adults. In any individual, concussive forces enact an alternate metabolic cascade that trigger a physiologic need for adenosine triphosphate for restoration; yet these metabolic changes harbor a downside, namely energy deficit and depressed neuronal activity, which appear to correlate with clinical symptoms such as headache, fatigue, dizziness, and slowed mental activity. In adolescents and youths, because these changes are occurring in a still developing brain, they may impart a more serious injury crisis and subsequent recovery.

As Rose and colleagues write in an article soon to be published in *Pediatric Neurology*, “Injury to the young, developing brain may be associated with greater risk of long-term functional impairments because of altered neuronal plasticity and immature myelination.”

The abnormal brain activity occurring after a concussion injury appears to set the stage for repeat concussions—both in the immediate term while the brain acts to restore itself, but also in the long-term if concussive injuries lower the impact threshold necessary for subsequent events.

In a recent article in *Frontiers in Neurology*, Semple and colleagues noted that “the brain is hypothesized to be more susceptible to subsequent injury after a concussion, such that sustaining a second impact while recovering from the first may result in prolonged and/or more severe symptoms.”

Although it is difficult to quantify the effects of repeat concussion in humans, the study by Semple et al reviewed animal...
models which suggest cognitive defects after repetitive but not after single concussion injuries. Those animal studies point to motor deficits after a single event that are magnified after repeat injuries, as well as delays in puberty and deleterious effects on sexual function. These behavioral and functional dysfunctions are in accordance with pathologic changes observed in animal studies, the Semple study said. Namely, neuronal injury is detectable after repeat but not single concussion events, “suggestive of an additive or cumulative effect.”

“Cognitive deficits are often reported after repetitive concussions to adult rodents in the absence of cell death, suggesting that a lower threshold of injury may be needed to induce functional deficits compared to that required for neuropathological changes,” the study authors wrote. Moreover, axonal injury, observable after a single event, may spur enhanced glial activation, in turn inciting an inflammatory response that persists even after symptom resolution, although the exact role of inflammation relative to concussion risk or recovery is not clear.

FOOTBALL, CONCUSSION, AND THE ROLE OF EDUCATION

If there is an inciting event for all the recent concussion talk, it may well be the publication of the Institute of Medicine (IOM) report Sports-Related Concussions in Youth: Improving the Science, Changing the Culture. As the authors acknowledged in the opening lines of the publication, “In the past decade, few issues at the intersection of medicine and sports have had as high a profile or have generated as much public interest as sports-related concussions.”

Yet the reach of concussion-related awareness has risen well above the level of interest at the intersection of sports and medicine. In 2009, the nation’s first law pertaining to the management of concussed youths, known as the Zackery Lystedt Law, was passed in the state of Washington. Since that time, all 50 states and the district of Columbia have followed suit with legislation intended to encourage greater concussion vigilance and, in most settings, established criteria for when and how athletes could return to play (RTP) after suffering a concussion.

One of the complicating factors identified by the IOM committee in understanding the importance of concussions and the need for legislation is a paucity of data on the actual incidence of concussions in youth and high-school athletes, as well as the role of education in changing an entrenched sports culture inherently resistant to reporting of concussions or concussion-like symptoms and adherence to responsible management plans.

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In surveys, youth profess that the game and the team are more important than their individual health and that they may play through a concussion to avoid letting down their teammates, coaches, schools, and parents,” the IOM report said.

A recent study by Dompier and colleagues provides a snapshot of concussion incidence among participants in youth, high school, and college-age football. Using board-certified athletic trainers who attended practices and games, the report found that concussions comprised 9.6 percent, 4.0 percent, and 8.0 percent of all injuries sustained and reported on among youth, high school, and collegiate football players.

The study noted a high number of concussion injuries occurring during practice, which is perhaps an underappreciated scenario for some to think about injuries occurring. Most of the concussions reported at the high school (57.7 percent) and college (57.6 percent) levels occurred during practices, although “the game concussion rate was higher than those for practices among all [three] levels of competition,” the study authors wrote.

In the study, the game concussion rate was highest for college athletes (3.74 per 1000 athlete exposures [AE]) compared with those for high school athletes (1.86 per 100 AE) and youth athletes (1.57 per 1000 AE). However, the practice concussion rate in college (0.53 per 1000 AE) was lower than in high school football participants (0.80 per 1000 AE).

“We have been collecting data from the NCAA for years, and there are more concussions in practice because there are simply more practices throughout the year,” said Thomas P. Dompier, PhD, ATC, lead author of the study, in an interview with Practical Neurology® magazine. “However, the rates in practice are lower than in games, and that’s due to the amount of exposures. Looking at the college data, there are 107 players on a
team. Sixty of those dress for games, but only about 40 people actually play. In practices, all 107 participate.”

Within the data, the researchers noted a decline in risk in the 2013 versus 2012 season, with the sharpest declines in rates among high school-aged participants. The authors speculated that the drop could have resulted from an effort designed to educate member coaches about concussions that was instituted by one of the school districts monitored for the study.

A further hint at the beneficial role of education and meaningful guidelines is provided by a subsequent study that Dr. Dompier was involved with, which was published recently in The Orthopedic Journal of Sports Medicine.1 The decision to publish the study in an open-access journal was meant to expedite its availability to concerned coaches and the sport community, Dr. Dompier said.

In the study, investigators intended to look at leagues running football programs for youths five to 15 years of age who did or did not institute the Heads Up Football (HUF) program, which includes education on tackling techniques, equipment, and other strategies intended to minimize concussions and other sports-related injuries. As the study progressed, it became apparent to the investigators that guidelines set in place by Pop Warner Football—one of the oldest and largest recreational football leagues—that established limits on player contact in practice might also be influencing injury rates (inclusive of concussions). At the time of publication, then, the investigators had compiled data on three groups of football programs: those with the HUF and practice restrictions, those with HUF only, and those that had not implemented HUF.

Overwhelmingly, the data pointed to a benefit of HUF and practice restriction, both in game and in practice settings.

Of the 370 injuries analyzed in the study, most were found to occur in practices, with the highest rates occurring during game situations. Practice injury rates were lowest among programs with HUF and practice restrictions (0.97 per 1000 AE) compared with the HUF only group (2.73 per 1000 AE) and the no HUF group (7.32 per 1000 AE). The game injury rate was lower in the HUF and practice restriction group (3.42 per 1000 athlete exposures [AE]) than in the HUF only group (13.76 per 1000 AE) and the no HUF group (13.42 per 1000 AE).

The researchers initially thought that practice restrictions would have no impact on game injuries; however, the all injury and time-loss injury rates were lowest in the HUF plus practice restriction group.

“Players in the [HUF plus practice restriction] group may enter games healthier because of the [Pop Warner Football practice contact restriction guidelines resulting in less contact exposure in practices],” the study authors wrote.

Overall, concussion events were most frequently reported in the no HUF group, followed by the HUF only group, and the HUF and practice restriction group. Statistically, the only difference among groups for concussion rates occurred among 11- to 15-year-olds in the HUF and practice restriction group (0.14 per 1000 AE) when compared with the no HUF group (0.79 per 1000 AE), which followed from a more general impression formed by the study investigators that HUF implementation and practice restrictions appeared to have greatest benefit among 11- to 15-year-olds. However, a low rate of concussion events limited analysis, the researchers wrote.

“Our findings suggest that a comprehensive coaching education program combined with practice guidelines limiting player-to-player contact may help lower injury rates,” the study said.

“With primary prevention, which includes policy and coaching changes, you can actually reduce concussions in practices,” said Dr. Dompier, who was also an author on the study. “Even though the practice rates of concusion at the youth and high school level are higher than what we would can hope for, the good news is that are ways to change that.”

CONCLUSION

Concussions in youth sports, and particularly among football players, has garnered much attention, and perhaps justifiably so. However, according to Dr. Dompier, football-related injuries are perhaps just the tip of the iceberg in what should be a larger discussion about how to mitigate concussion risks in all sporting endeavors. In particular participants in other sports, and certain demographics of athletes, may be underserved if the entirety of attention rests on high-profile football-related injuries.

“Females don’t get as much publicity,” Dr. Dompier said. “Even with the women just winning the World Cup, it is surprising there is not more discussion about concussions in girls soccer, because their rates are pretty high as well. Other sports like wrestling at the college level have rates that are higher than football, but no one talks about these other sports. If there is anything we should do is we should consider football in context of other sports.”

“I think we are doing the female athletes a disservice if we aren’t trying to protect them as well,” Dr. Dompier said.