Making Sports Safer for Kids

By Leslie Mertz

Using Biomechanical Devices to Prevent Injuries

Children seem so resilient. They can fall off a moving bike and get right up off the ground, seemingly no worse for the wear. They can leap off the side of a hill and land hard but run off with an ease that makes adults jealous.

Nonetheless, kids can and do get hurt, and sometimes those injuries are difficult to spot. A growing number of research groups and companies are now turning their attention from professional and college athletes to schoolchildren aged 6–18 years to learn how to make sports as safe as possible.

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"One of the things we're doing now is taking everything we've done with concussions in college football [see "Putting the Hit on Concussions"] and translating it to youth football players," said Steven Rowson, Jr., Ph.D., research assistant professor in the Virginia Tech-Wake Forest University School of Biomedical Engineering and Sciences and its Center for Injury Biomechanics. "We're doing this work because there are 3.5 million youth football players (in the United States), which is far more than players at the college or professional levels. Yet, there's so much less that is currently known about pediatric tolerances to head impacts" [1].

Two years ago, researchers took two first steps to bridge that gap. They started recruiting local youth players and have so

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far gathered data about head trauma from 119 children aged 6–18 years. On the basis of preliminary data, they found that a typical child can experience impacts as hard as college players, but they occur much less frequently.

"We were actually surprised at the speeds at which these kids play," Rowson said. "The head accelerations in eight-year-olds were sometimes just as high as those we see in college players, partly because they impact their heads in the same scenarios as adult players. Our data show that these kids can experience 80–100 Gs resulting from the more severe impacts," he said, noting that a 100-G impact is enough to cause a concussion.

The researchers have developed a biomechanical surrogate that models a child's response to impact observed in sports.

One of the ways that Virginia Tech gathers data from the children is with the use of the Head Impact Telemetry (HIT) system (see "Putting the Hit on Concussions"), a combination of six accelerometers and a radio telemetry unit mounted inside a football helmet. A product of Riddell Sports, Inc., Elyria, Ohio, the instrumented helmets, called the Sideline Response System, track head accelerations and wirelessly transmit the gathered data to computers on the sidelines. The helmets are great resources for researchers, but parents and coaches want a more inexpensive version of the instrumented helmets, which run about US$1,000 apiece, that can alert them when a child has taken a potentially concussion-causing hit.

Riddell is planning to roll out such a system. "There's been a lot of interest in getting this type of technology and impact monitoring down to the youth and high school level," said Richard Greenwald, Ph.D., president of Simbex. Simbex developed both the HIT system and the technology for the new youth helmet, which Riddell calls the InSite Impact Response system (Figure 1).

"The InSite system is less of a research tool (than the Sideline Response System) in that not every impact is stored. Instead, it's a monitoring system," Greenwald said. Although it is not a diagnostic device, it sends out an alert if an athlete takes a hit or series of hits above a predetermined magnitude, which is based on the athlete's playing level and position, because different positions have different frequencies and severities of hits. "This is very important because there are questions about how cumulative impacts over time might affect both short- and long-term brain health."

FIGURE 1 The new InSite Impact Response system from Riddell Sports, Inc. (Photo courtesy of Riddell Sports, Inc.)

For the InSite system, Jeffrey Chu, Simbex director of engineering, changed the base technology from the HIT system's accelerometers to an electret film (Figure 2). "The significant benefits of the electret film are in power consumption and cost. The new InSite system will run on a single battery for an entire season, compared to the HIT system, which has to be charged every couple of weeks," Greenwald said. "That's an important consideration for use in youth and high school sports where maintenance and battery charging might otherwise be challenging in widespread use."

According to Thad Ide, senior vice president of research and product development for Riddell, this system is different from other technologies. "Riddell InSite is grounded in research and was developed based on years of data collected by Riddell SRS. Its alert methodology is based on 2 million recorded on-field impacts and uses HITsp, a published index that combines linear and rotational acceleration, duration, and location of impact." The new InSite system became available for purchase in July and will be seen on football fields this fall.

Meanwhile, at Wayne State University in Detroit, Michigan, researchers are focusing on commotio cordis, a potentially lethal condition that can follow a hard blow to the chest. "What happens is the heart goes into an irregular rhythm, and unless they get cardioverted (defibrillated via electricity), the patients won't survive even if they get CPR," explained Cynthia Bir, Ph.D., who left her position in Wayne State's Department of Biomedical Engineering to become a professor of research at the University of Southern California's Center for Trauma, Violence, and Injury Prevention in Los Angeles. Commotio cordis is the second leading cause of mortality in youth sports.

FIGURE 2 Developed by researchers at the Ohio-based company Simbex, the technology behind the InSite system includes an electret film within the helmet's liner assembly. The electret film allows the system to run on a single battery for an entire season. (Photo courtesy of Riddell Sports, Inc.)

Putting the Hit on Concussions

Concussions, a type of traumatic head injury common in contact sports, have gained considerable attention over the last few years as concern about the long-term effects of multiple concussions has grown.

For the past decade, researchers at several universities, including Virginia Tech, have been tracking the jarring head impacts experienced by their football players. "We're looking at the biomechanics associated with concussions and trying to find different ways to reduce those situations," said Steven Rowson, Jr., Ph.D., research assistant professor in the Virginia Tech-Wake Forest University School of Biomedical Engineering and Sciences and its Center for Injury Biomechanics.

At the core of the research is the HIT system, a technology developed and marketed by Simbex, a product-development company based in Lebanon, New Hampshire. The HIT system measures head-impact exposure on the sporting field through a set of six accelerometers and a radio telemetry unit mounted inside a helmet made by Riddell Sports, Inc. "It's critically important that the accelerometers are contacting the head during the impact. In football helmets, foam padding acts as a spring to decouple the helmet from the head and allows us to measure head acceleration and not helmet acceleration," said Simbex's president, Richard Greenwald, Ph.D.

The HIT system measures head-impact exposure on the sporting field through a set of six accelerometers and a radio telemetry unit mounted inside a helmet made by Riddell Sports, Inc.

The data from the instrumented helmets, which Riddell markets as the Sideline Response System, are transmitted wirelessly to a computer for analysis. "While the players are participating in games and practices throughout the season, we're actively collecting data for every head impact that instrumented players experience," Rowson said [S1]. "Through these past ten years of collecting data, we've learned exactly where, how hard, and how frequently each helmet is hit and whether each hit happened during a game or a practice."

For instance, the Virginia Tech researchers now understand more about accelerations and the associated risk of injury. "While there are likely different tolerances associated with different impact locations on the head, in general we see that the average concussive impact has a head acceleration of around 100 Gs," Rowson said. For comparison, that kind of acceleration is comparable to hitting a wall at 20 mi/h.

One of the more surprising findings from their lab tests was that the Virginia Tech football team was using a helmet that, although it passed all safety standards, was not especially good at shielding the players from the impacts associated with concussions. "The football team came to us and asked us what helmet they should use. Although we had never really addressed that question in the past, we had years of data collected directly from our players, so we emulated on-field impact conditions in the lab and started evaluating helmets," Rowson said.

They assessed the helmets using the Summation of Tests for the Analysis of Risk (STAR) evaluation system, a one- to five-star rating system that Rowson developed for his Ph.D. dissertation research several years ago. The system is based on collected field data—the cumulative frequency, magnitude, and location of impact events—and an athlete's risk for concussion [S2]. "If an athlete experiences a given head acceleration, for instance, a risk analysis determines the probability of a concussion for that acceleration. By combining the head impact exposure data with the risk component, we can theoretically predict the number of concussions that a player would experience wearing a specific helmet. These principles are applied to drop tests in the laboratory to evaluate helmets (putting a helmet on a head form and literally dropping it onto a hard surface)."

So far, the research group has evaluated 18 helmets. "We found that the Virginia Tech football players were in a helmet that didn't perform very well in our laboratory tests compared to newer helmet models, so based on the on-the-field and laboratory data, we were able to make a recommendation for a different helmet. The entire team adopted it."

It has made a difference. "We see an 85% reduction in concussion rate between the helmet they were using and the helmet they switched to," Rowson said.

Helmet research will continue with a new linear impactor (Figure S1), according to Rowson. "Using this device, we are striking the head form with an impactor ram (Figure S2), rather than dropping the head form. This allows us to look at linear and

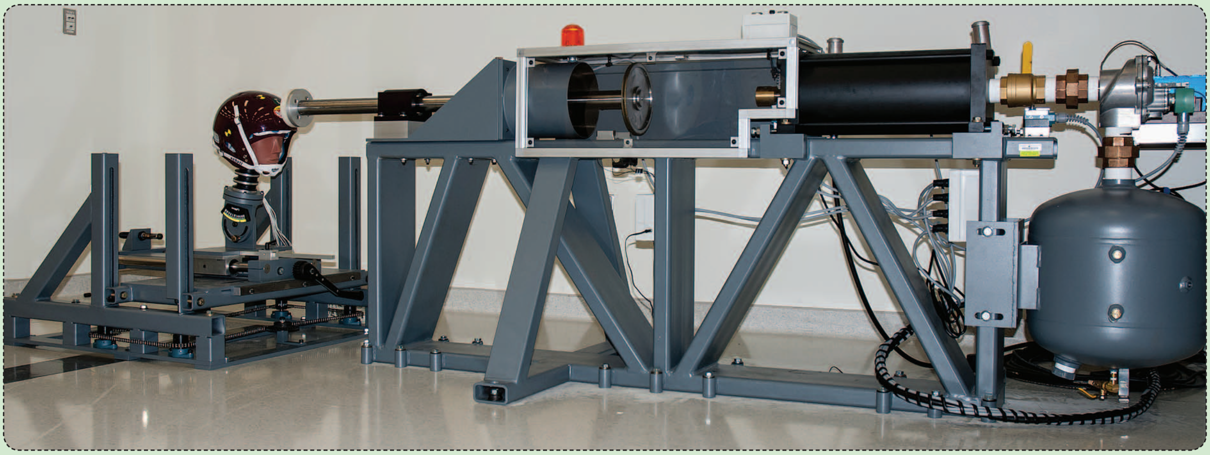

FIGURE S1 Using the STAR evaluation system developed by Steven Rowson, Virginia Tech researchers are learning more about the head accelerations that players experience and the associated risk of concussion. This linear accelerator allows the researchers to select acceleration as well as the precise location of impact on a helmeted head form. (Photo courtesy of Steven Rowson.)

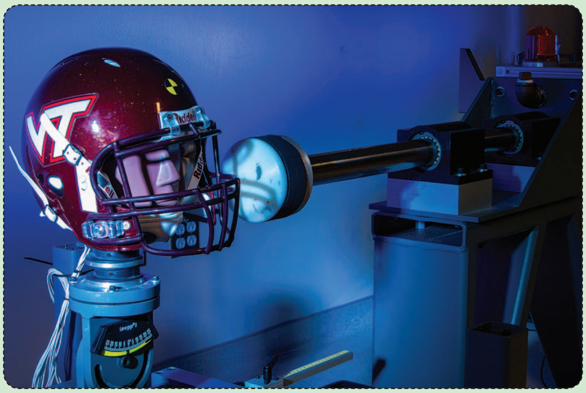

FIGURE S2 With funding from the National Institutes of Health, the Virginia Tech researchers are testing football helmets for the ability to prevent injury. After evaluating 18 helmets, they recommended one to the university football team. Since the team made the switch to the new helmet, the concussion rate has dropped by 85%. (Photo courtesy of Steven Rowson.)

rotational accelerations of the head, which will provide a more comprehensive method of evaluating helmet design."

The researchers will soon be expanding their interest to concussions in other sports, such as hockey, lacrosse, baseball, and softball.

Outside of concussions, the researchers have also studied an injury called a stinger. A stinger is caused by either the excessive hyperextension of the neck or a combination of hyperextension and lateral flexion of the neck, resulting in an injury to the brachial plexus, a network of nerve fibers that run from the cervical spine down the arm. "It's a transient injury, but it's very troublesome for a lot of players who seem to be more prone to it," Rowson said.

Manufacturers have developed neck collars designed to limit extension and lateral flexion in the neck, and many players swear by them. The Virginia Tech researchers wanted to see how effective they were, so they tested different collars using the linear impactor and a crash-test dummy decked out in football gear. "We've been able to relate the forces in the neck to the range of motion that the collars restrict," Rowson explained.

Their laboratory tests have not shown much of a reduction of loads or range of motion in most of the collars they have tested, he said, but they have found some exceptions, including one collar that limited range of motion to such an extent that the players did not like to wear it. Rowson commented, "It's a tradeoff, and it shows that protective equipment can pose some difficult design problems."

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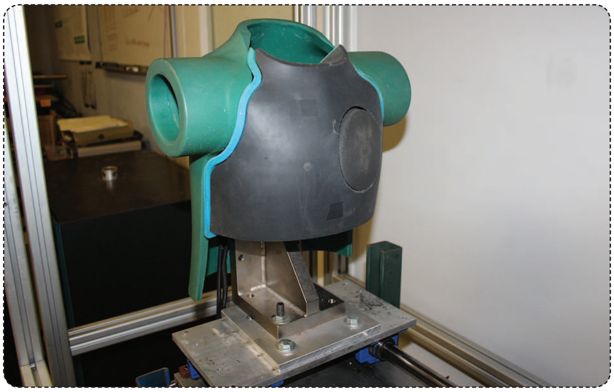

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FIGURE 3 Researchers at Wayne State University developed this biomechanical surrogate that models a child's response to impact observed in sports, including the impact that can cause commotio cordis. Commotio cordis, which causes a life-threatening heart arrhythmia, is a leading cause of mortality in youth sports. Researchers describe the surrogate, officially named the Sports Specific Thoracic Surrogate, as the first-available model on which children's chest protectors can be tested. (Photo courtesy of Wayne State University.)

The researchers have developed a biomechanical surrogate that models a child's response to impact observed in sports (Figure 3). Specifically, the surrogate is designed to serve as a model on which children's chest protectors can be tested, said Bir. Nathan Dau, one of Bir's doctoral students, spearheaded the surrogate project [2].

To develop the surrogate, they conducted animal testing and combined their findings with data gathered from cadavers. The resulting model, called the Sports Specific Thoracic Surrogate, was completed last year.

Until this surrogate became available, testing chest protectors was difficult, Bir said. "The reality is that some of these protectors are not as effective as the manufacturers claim, so with this new surrogate that we've developed, we're now able to make the assessments and determine whether various chest protectors actually will help reduce the incidence of commotio cordis."

Research on youth sports is critical, Bir remarked. "This kind of work translates into my own life and my children's lives. I have four kids, including a daughter who's doing gymnastics. I'm constantly trying to figure out ways to keep her from being injured." She added, "And really, that's what's exciting about biomedical engineering: What we're doing in the lab translates to the real world. Our work is making sports safer for our kids."

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