

After a concussion, when is it safe to go back in the game?

November 13 2015, by Sara Lajeunesse



At Penn State's Center for Sport Concussion Research and Service, a young athlete uses a remote control device to navigate through a virtual room to test his balance and ability to adjust quickly to a changing scene. All Penn State varsity athletes and many younger athletes from the local community undergo testing before their practice season starts, to provide baseline performance levels. Athletes who later suffer a concussion undergo testing after their injury, to monitor their recovery. Credit: Patrick Mansell, Penn State

Lacing up her high tops one blustery morning in February 2009, Krista Krebs had no idea her career as a high school athlete would be over precisely 45 minutes later. "It wasn't the way I imagined senior year to end," she says.

The moment occurred when she was chasing down a basketball during a routine scrimmage. As she bent low to grab the ball, a racing teammate arrived at the spot at the same time. The teammate's shoe slammed into Krebs's left temple. The blow left Krebs with a concussion from which she has still not recovered, even after pursuing a variety of treatments. Six years later, Krebs continues to suffer from a constant headache and from episodes—which include slurred speech, slumping over, trouble walking, and muscle weakness—when she works too hard.

A silent epidemic

[According to the Centers for Disease Control and Prevention](#), in the United States an estimated 1.7 million people suffer a concussion, or traumatic brain injury, each year. Most recover fully, but some suffer side effects for the rest of their lives. Although the media tend to focus on sports-related concussions, these account for only about 15 percent of the total. Falls, especially by children and older adults, account for far more—40 percent, or about 680,000 concussions per year. Other causes include unintentional blunt trauma to the head (15 percent), motor vehicle crashes (14 percent), and assaults (10 percent).

With concussions so common, it's surprising to learn that scientists and medical professionals don't know much about them. According to Dr. Wayne Sebastianelli, Kalenak Professor and medical director of orthopaedic surgery at University Park, there isn't even a satisfactory definition for the term. "We do know that concussions involve a

disconnect between the brain's processing of information and the energy that's required to do that processing," he says. "So if one part of the brain is injured, all the surrounding areas have to work harder to try to get normal information processed, but to do that, they require more energy, which takes away energy that's needed for the injured part to heal. It creates a negative cycle."

Semyon Slobounov, professor of kinesiology at Penn State, adds that the severity of a concussion is difficult to diagnose because symptoms—which can include headaches, dizziness, nausea, difficulty concentrating, difficulty balancing, light sensitivity, seizures, depression, and personality changes—can vary widely by individual and by the location and severity of the injury.

This lack of understanding about the biology of concussions means that no good treatments exist. The prescription is usually rest and relaxation to give the brain a chance to recover. "In the past, people often blew off concussions as badges of honor and went right back into the game," says Sebastianelli. "But we now know that the effects of a concussion can become worse if the brain isn't given adequate time to recover."

Worse indeed. In fact, a second concussion within days of the first can cause cerebral edema and herniation, leading to collapse and even death. So how long does a patient need to sit out before it's safe to go back into the game? Determining that, according to Slobounov, is one of the goals of his and his colleagues' research in Penn State's Center for Sport Concussion Research and Service in the College of Health and Human Development.

Diagnosing and recovering from concussion

The severity of a concussion is hard to diagnose because the symptoms can vary widely depending on the individual and on the location and

severity of the injury. Recovery from concussion can be even harder to diagnose, because some patients who do fine in traditional tests may harbor lingering problems that can surface months or years later.

Baseline testing

Try this: Stand up and put one foot directly in front of the other, heel to toe. Now imagine maintaining that stance while the room around you rocks, dips, and sways. "It's not as easy as it seems to stay balanced," says research technologist Katie Finelli.

Finelli is responsible for administering this balance test to patients before and after they become injured. The test is set in a virtual-reality environment viewable by looking through 3D glasses at the image of a room projected onto a screen. She also administers a virtual-reality memory test in which a computer directs patients through a series of 3D hallways and rooms on the screen. The patient must pay close attention and then repeat the route using a joystick navigation device. Finally, Finelli oversees a reaction test in which patients must move their bodies in specific ways in response to the movement of a 3D room projected onto the screen. "We place an accelerometer on the patient's head so we can track his or her head movements," says Finelli. "For balance, we monitor displacement from the patient's starting point, and using that raw data we score him or her, with 10 being wonderful and zero being can't stand up."



Krista Krebs, now a senior, has excelled at Penn State despite ongoing effects from a concussion she suffered in 2009. "It's a new normal for me," she says. Credit: Patrick Mansell, Penn State

The virtual-reality tests were developed by HeadRehab LLC, a Chicago-based company that sponsors laboratory and clinical research into head trauma. The Penn State research team pioneered their use in a program that aims to get a better handle on the symptoms being experienced by an athlete with a concussion and to enable doctors to provide proper treatment. A concussed soccer player may appear to be fine after a week of rest, but if the tests reveal that his ability to balance still lags behind his pre-concussion ability, he should rest a while longer.

"Our baseline-testing program uses a combination of virtual-reality testing, plus computer-based cognitive and standard balance testing, to examine executive function, reaction time, memory, and balance—really all the symptoms of concussive injury," says Slobounov.

The team's patients include both Penn State athletes and younger athletes from the surrounding community. The services are provided free of charge for the former and for a small fee for everyone else. Penn State athletes are required to take the computer-based cognitive and standard balance tests before their practice seasons start. The virtual-reality test is optional. "This year, 70 percent of our student athletes participated in the virtual-reality test," says Tim Bream, director of athletic training services and head football athletic trainer at Penn State. He notes that over the last three years for all varsity sports—plus rugby, a club sport—the average number of concussions diagnosed at Penn State per year was around 30, or 3 percent of student athletes.

Bream says the computer-based cognitive test and standard balance test are part of the [protocol](#) that Penn State uses to determine when and if athletes can return to play. "We use the tests every day until the students are symptom free," he says. "Once they are symptom free, they start another part of the protocol, which is light exercise, followed by heavier exercise, followed by an examination by a physician."

Slobounov says that the virtual-reality tests, which are now being used in some form by numerous other colleges and universities, are important because they reveal cognitive and motor abnormalities that do not show up in traditional tests. This is key because, as his research has demonstrated, some patients who do not exhibit symptoms may harbor problems that will surface years down the road.

To examine these hidden abnormalities, Slobounov conducts the virtual-reality testing in conjunction with electroencephalogram (EEG) imaging

and sometimes with other imaging techniques, such as functional magnetic resonance imaging (fMRI). "We are looking at the relationship between how the patient performs on the test and what is going on in his or her brain," he says. "It's the most robust way to test structural and functional abnormalities."

The emotional trauma of traumatic brain injury

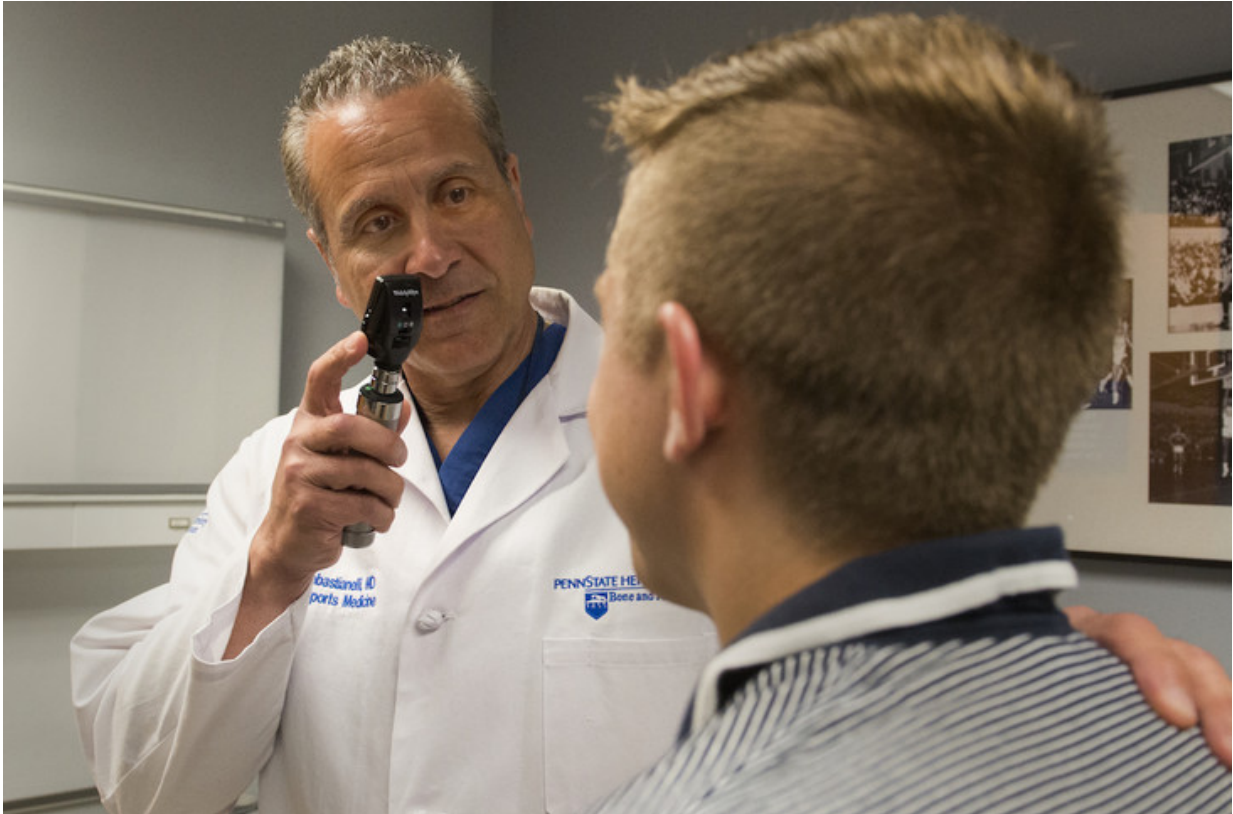
While most victims of [traumatic brain injury](#) recover all or some of their cognitive function, a significant percentage either never improve, or decline and die.

Samantha Hall was one of those who lost her life, passing away last winter after two years in a vegetative state following a car accident. "You're left with this curled up body in a bed that weighs less than 80 pounds," says her brother William Doan, professor of theatre and of women's studies. "You think, 'How can that be my sister?'"

As Doan grieved over Samantha's condition, he spent countless hours learning about diffuse axonal injury, the form of concussion she suffered, in which the damage is widespread rather than focused in one area of the brain. "I wanted to find out what my sister could be feeling and experiencing, because early on she was in what would be considered a minimally conscious state, where there seemed to be some verifiable form of awareness," he says. "There was even a brief window where we were able to get her to blink once for yes and twice for no. But then her eyes would glaze over. You could literally see her go from awareness to lack of awareness. I became desperate to understand. If she's not coming to the surface anymore, does that mean she doesn't hear me?"

At the same time Doan was searching for answers, he was also functioning as an artist, writing poems and eventually a play about the experience. His play, "Drifting," is set in a hospital room. The patient,

who represents Doan's sister, is in a coma and periodically has out-of-body experiences in which she converses with her brother. "The conversations are part memory, part fantasy," says Doan. "Writing the play in this way gave me an opportunity to explore what my sister might be experiencing."



Dr. Wayne Sebastianelli, medical director of orthopaedic surgery at University Park, examines a patient for signs of concussion. At the Center for Sport Concussion Research and Service, Sebastianelli and colleagues are exploring how to better diagnose the damage caused by a concussion and how to determine when a person who has suffered a concussion can safely return to normal activities. Credit: Patrick Mansell, Penn State

So far, the play (directed by Andrew Belser, professor of theatre at Penn State) has been performed off-Broadway in New York City and for students at the Penn State College of Medicine. Doan says the process of writing it helped him and his family when the time came to remove his sister's artificial nutrition and hydration.

"It was important for us to fully understand the situation so we could make the best possible decision," he says. "With 'Drifting,' I really want my audience to understand the complexity of living in a world that essentially chooses to save life no matter what the cost. That isn't always the best course of action."

A new normal

Doan's sister did not survive her extensive head trauma. Most concussions are much less severe, which makes them survivable—but can also make them easy to shrug off as being "not that serious."

All concussions are serious, says Sebastianelli, and how they are managed is crucial. The key to recovery, where recovery is possible, is what he calls "relative rest."



Research technologist Katie Finelli administers a balance test to a young athlete prior to hockey season. The athlete will use a remote control device to navigate through a virtual room that may dip, tilt, and sway. This is a sensitive test for recovery from damage to parts of the brain involved with balance and kinesthetic sense. Credit: Patrick Mansell, Penn State

"Essentially, it's activity below a level that creates symptoms," he explains. "If you can walk and not get a headache, then you can walk. If you get a headache when you walk, you shouldn't walk." Other symptoms to watch for include dizziness, sensitivity to light, and inability to concentrate. The relative rest might apply to mental work, too—taking a break from academics, working on your computer, even playing video games or reading.

As the brain recovers and the symptoms abate, the patient can gradually start doing more—although for some, like Krista Krebs, problems linger.

She rested and got treatment for an extended time after her injury, and delayed going to college for a year. She entered Penn State as a part-time student in the fall of 2010 and has excelled, scoring a near-perfect 3.99 grade-point average and doing creative work as an app developer during internships. Even so, she faces daily reminders of her [concussion](#).

"What's hardest is when I'm going to sleep at night, when I realize my head still hurts and I have to get up and do it again tomorrow," she says. "But then I wake up as I've done for thousands of days in a row now, and I just carry on. It's a new normal for me."

Most people who suffer a blow to the head can eventually return to a normal that's just like their old normal. But their recovery depends on taking the trauma seriously.

"Creating a culture of awareness of head injury is very, very important so that it can be appropriately recognized and treated," says Sebastianelli. "Concussion is not a badge of honor. It's an injury."

Provided by Pennsylvania State University

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