Using Reaction Time Measurements to Avoid Long-term Effects of Brain Injuries

PISON®

Measuring an athlete's reaction time can help determine whether to rest or consult with a doctor after concussive and subconcussive head contact

The Priority: Lower the Long-Term Health Risks

For athletes at any level—youth, high school, college and professional—brain trauma is a major concern. Everyone wants to enjoy the benefits of sports, which include improved physical and mental fitness, the joy of competition, and the satisfaction that comes from increasing skills to a higher level. However, none of these benefits should come at the expense of long-term health.

In recent years, knowledge of the dangers of repeated head injuries has greatly increased. This is in part due to the 2002 discovery of Chronic Traumatic Encephalopathy (CTE), a degenerative brain disease linked to repeated concussions and subconcussive head contact.

Today, the prevailing medical advice is that a person suffering from a concussion should stay out of the action until their brain heals. However, CTE symptoms don't develop right after a head injury. Research suggests that CTE develops over years or decades of repeated head trauma.[1] There is also growing concern that repeated head injuries, especially if received before the brain has healed from a previous injury, may lead to permanent damage or a higher risk of neurodegenerative disorders later in life.[2]

However, despite increased awareness of safety measures and concussion protocol, many concussions and head injuries still go undiagnosed. This leaves athletes at risk of suffering permanent damage.

In this white paper, we explain how an athlete's reaction time is affected by brain trauma. We also explore how integrating a simple reaction time test into the course of practice and play could help determine whether an athlete should sit out or seek a doctor for a formal medical diagnosis. The paper then discusses the benefits of Pison's wrist-worn device for reaction-time testing, which delivers accurate results useful in detecting impairments, and is easy to administer on the playing field, during practices, and at home.

The Connection Between Blunt-Force Trauma and Reaction Time

Research studies have shown that when an athlete's brain is subject to blunt-force trauma that results in a concussion, their reaction time degrades.[3] An athlete's reaction time has been shown to increase (i.e., worsen) by 10% within six hours of suffering a concussion. Their reaction time can remain elevated even for a couple of months after a concussion before returning to the pre-concussion baseline.[4]

In addition, Pison studies conducted with the US Department of Defense have shown that reaction time can also degrade when a person is exposed to multiple, smaller blasts from explosives during training. This holds true, even when each blast or blow would not cause a concussion on its own, i.e. the person is exposed to multiple subconcussive events.[5]

Subconcussive incidents may occur within a short period of time or over the course of a week, a month, or a season. By definition, one of these incidents does not cause a concussion. But a growing body of evidence shows that permanent

1. US Centers for Disease Control and Prevention.
2. *Long-Term Cognitive and Neuropsychiatric Consequences of Repetitive Concussion and Head-Impact Exposure,* Thomas McAllister, MD and Michael McCrea, PhD, ABPP, Journal of Athletic Training, March 2017.
3. *Effect of sport-related concussion on clinically measured simple reaction time,* National Library of Medicine, 2014.
4. *Examination of Reaction Time Deficits Following Concussion: A Systematic Review and Meta-analysis,* Landon B. Lempke and others, Sports Medicine, March 11, 2020.
5. Pison reaction time tests of (DoD branch) soldiers exposed to multiple blast waves in a single day while training to breach locked doors with explosives, November 2023.

brain injuries can occur from the cumulative effect of multiple subconcussive blows to the head.[6,7,8]

Pison's own study shows that repeated incidents do increase reaction time, which suggests that multiple incidents have had a cumulative impairment on the brain. An important danger of subconcussive blows is that athletes, along with their coaches, trainers, and parents may not even be aware when this form of trauma occurs.

What Is Reaction time?

Reaction time, measured in milliseconds, indicates the elapsed time it takes an individual to respond once they are delivered a stimulus prompt, such as a visual, audible, or tactile signal. In sports, reaction time reflects the information processing capabilities of an athlete's nervous system and their readiness to respond to the actions of their teammates and their opponents:

- Can the baseball outfielder break early enough on a swing to reach a fly ball in the gap?
- Does the football linebacker react to the snap of the ball fast enough to pressure the quarterback?
- Can the ice hockey goalie save a slap shot coming at 100 miles per hour?

The reaction time test has become one of the elemental measurements to estimate how quickly and effectively athletes can execute these types of mental operations. This single test can measure the processing efficiency of an athlete's brain functions—such as sensory perception, executive function, motor planning, and motor execution.

Head Trauma Affects Many Sports

Participants in many sports face the risk of head injury, whether they are classified as contact sports or not.

To illustrate the risk of concussions, the National Collegiate Athletic Association (NCAA) conducted a study to estimate the concussion rates for men and women across multiple sports:[9]

In addition to these sports, any sport that involves rapid movement can lead to an athlete experiencing blunt-force trauma to their brain. These include individual sports such as diving, bicycling, speed skating, and race car driving.

Concussion Rate (per 1,000 athlete exposures)

Men	During Games	During Practices
Baseball	0.16	0.04
Basketball	0.53	0.34
Football	3.25	0.48
Ice Hockey	2.40	0.20
Lacrosse	0.91	0.19
Soccer	0.67	0.14
Wrestling	4.31	0.48
Women		
Basketball	1.00	0.39
Ice Hockey	2.11	0.31
Lacrosse	1.28	0.25
Soccer	1.65	0.18
Softball	0.42	0.18
Volleyball	0.64	0.27

Source: Cumulative Head Impact Exposure Predicts Later-Life Depression, Apathy, Executive Dysfunction, and Cognitive Impairment in Former High School and College Football Players, Philip H. Montenigro and others, Journal of Neurotrauma, April 2016.

Why Monitor Reaction Time?

Despite awareness of the prevalence of concussions and the importance of detecting them early so that athletes can

6. *Cumulative Head Impact Exposure Predicts Later-Life Depression, Apathy, Executive Dysfunction, and Cognitive Impairment in Former High School and College Football Players,* Philip H. Montenigro and others, Journal of Neurotrauma, April 2016.
7. *Collective Force of Head Hits, Not Just the Number of Them, Increases Odds of C.T.E.,* Daniel H. Daneshvar and others, BrainLine, June 23, 2023.
8. *Leveraging football accelerometer data to quantify associations between repetitive head impacts and chronic traumatic encephalopathy in males,* Daniel H. Daneshvar and others, Nature Communications, June 20, 2023.
9. *Epidemiologic Measures for Quantifying the Incidence of Concussion in National Collegiate Athletic Association Sports,* Zachary Y. Kerr and others, Journal of Athletic Training, March 2017.

can recover, it is startling that nearly 30% of athletes report having a concussion that went unreported and undetected.[10]

The number of athletes at risk of long-term head injury is even greater when considering the effects of multiple subconcussive blows over time. The data is just beginning to enter the consciousness of athletes, their teams, and trainers as the first conclusive research studies are published. Since reaction time can be negatively affected by both concussive and subconcussive blows, it represents a potential tool to gain greater insights into the health of athletes and expose vulnerabilities that currently cannot be detected.

A key point of emphasis is that reaction time results do not provide a medical diagnosis of whether an athlete has been concussed or is subject to subconcussive brain trauma. A reaction time test is similar to taking a person's temperature or measuring their blood oxygen saturation (sO2) at the fingertip. The results can help determine if they need to take precautionary steps on their own or if it's time to see a doctor.

Establishing Reaction TIme Routines

For reaction time measurements to be meaningful during a game or practice—when it is suspected an athlete has experienced brain trauma—it's critical for athletes to have previously maintained a consistent reaction time testing routine. A good test hygiene routine gives athletes, parents, coaches, and trainers an accurate baseline to measure against to later determine if a brain injury might have occurred.

To establish a reliable baseline, the routine should include daily testing for two weeks before the season starts. The testing should occur while the athlete is well-rested and alert. Once the season starts, reaction time tests should be administered weekly. This will help identify if any regression has occurred, perhaps due to a series of relatively minor blows to the head.

The test should also be immediately taken during a game or practice any time an athlete experiences a blow to the head. That measurement should be followed by testing throughout the day (perhaps every few hours) and the following days to track the athlete's reaction time vs. their baseline.

To guard against undetected concussions or cumulative subconcussive blows, contact sports teams—such as football and ice hockey, where multiple hits can be absorbed each practice—could test reaction time before and after practice. This compares a player's current state to their long-term baseline to see if a decline has occurred. This approach could be extended to other sports, such as soccer, where contact is less common but can still be intense.

The results of any reaction time test should never be interpreted on their own as a conclusive diagnosis that a concussion or other brain injury has occurred. They should simply be used as a guide to determine if it's time for an athlete to rest or to see a doctor.

Recomended Reaction Time Testing Routine
• Establish a baseline
• Monitor regularly to determine if subconcussive blows affect cognitive health (post-game and post-practice).
• Monitor immediately after violent blows to the head (even if no symptoms exist).
• If reduction in reaction time is detected, rest and see a doctor.

The Challenges of Traditional Reaction Time Testing Systems

The type of regular reaction time testing proposed earlier may not be feasible given traditional reaction time testing equipment. Tests are often conducted using online computerized assessments—where users interact with a testing website or application through a laptop, desktop, or mobile device. These computer-based systems have significant drawbacks:

- **Inaccuracy due to system delays**—Testing systems that involve monitors, computers, keyboards, mice or touchscreens introduce errors that render reaction time readings unreliable. For example, the time to show the stimulus on the screen, press the mouse button, and

10. *The Prevalence of Undiagnosed Concussions in Athletes, William P. Meehan, III, MD and others.* Clinical Journal of Sport Medicine, September 2013.

register the signal all introduce timing variabilities and mechanical delays that interfere with the results and mask the cognitive issues being measured.[11] The latency of these systems is often as high as 40 milliseconds, whereas a 20 millisecond degradation of reaction time could indicate that a brain injury has occurred.[12]

- **Lack of access**—Elite athletes may have access to reaction time testing through their performance coaches and sophisticated training facilities. Casual adult athletes and athletes at the youth and high school levels rarely, if ever, have access to reaction time tests.

- **Inconvenient for the performance environment**—Traditional reaction time testing systems are difficult to administer in the middle of commotion on the sideline or bench during a game or a practice. Instead, they are set up outside of the sports performance environment, such as in the trainer's office, at a clinic, or in a computer room. That means measuring abilities are unavailable when needed at the playing field, making it impossible to gauge reaction time when it matters most. Players also can't monitor themselves under all conditions, such as when they are at home or on the playing field under stress.

A Wrist Worn Device for Convenient, Accurate Testing

Athletes, coaches, trainers, and parents who want to accurately measure and track reaction time to help prevent long-term brain injuries can turn to Pison, which offers a lightweight, wrist-worn device to facilitate testing during game and practice situations. The device uses Pison's novel neural sensor and artificial intelligence algorithms to immediately gauge the athlete's neuromuscular signals, a far more direct measurement than traditional reaction time tests.

Pison devices provide two advantages over other reaction time monitoring systems. The first is **convenience**. With the wrist-worn device, teams and athletes can run tests anytime and anywhere.

Tests take just 20 seconds, allowing athletes to measure more often and under different conditions. Regularly conducting these cognitive tests provides new insights not only into impairment from head injury, but also the effectiveness of training and preparation and impairment from lifestyle habits.

The second advantage is **accuracy**. The self-contained Pison devices generate stimuli and then measure neural reactions directly off the same system clock. This eliminates the delays of computer-based testing systems and allows Pison to measure reaction time without the variability introduced by computer-based reaction time tests. This results in repeatable and reliable test times with one millisecond (0.001 seconds) precision and allows athletes and teams to detect impairments that would have been more difficult to detect—considering the noise and variability inherent in other computer-based systems.

In addition, Pison provides an accurate measurement of the premotor time, which is the time it takes for the individual to sense the stimulus and the brain to send electrical signals to the hand to excite the muscles to respond. With this information, users gain an objective measure of the responsiveness of their brain and can gauge the impact of mental and physical exercises on their nervous system.

Pison not only provides the means to measure core reaction time, but also allows athletes and teams to measure two other key cognitive scores: 1) mental agility—with a 60-second Go/No-Go choice reaction time test; and 2) cognitive focus—a three-minute psychomotor vigilance test showing the ability to maintain attention and focus on tasks.

While the Pison device is designed for individual athletes to measure their personal reaction times, Pison also provides coaches and trainers with the ability to monitor their entire roster with cloud data sharing and team dashboards. A single device can be shared by the team on the sideline by a coach or trainer testing players on their smartphone and noting the test conditions—such as whether the player is at rest, during the pre-season, or has just suffered a blow to the head.

11. *Methodological Problems With Online Concussion Testing, Jameson Holden and others,* Frontiers in Human Neuroscience, October 1, 2020.
12. *Interpreting Clinical Reaction Time Change and Recovery After Concussion: A Baseline Versus Norm-Based Cutoff Score Comparison,* Jaclyn B Caccese and others, Journal of Athletic Training, August 1, 2021.

Maintaining Safe Environments for Athletes of All Ages

Athletes ranging from youth sports to professionals all need a fast and convenient way to gauge their reaction time and cognitive health. This metric provides athletes, parents, coaches, and trainers more information to identify when it's time to rest or to see a doctor due to some form of suspected brain trauma, be it the possibility of a concussion or subconcussive injury.

With Pison wrist-worn devices for testing reaction time, athletes now have a way to detect possible brain injuries that would otherwise go undetected. Pison devices are stand-alone systems that feature a LED that delivers a visual stimulus and a neural sensor for sensing user responses. This approach provides a more accurate and reliable measurement of reaction time compared to computer-based systems with multiple components. Pison devices are also convenient for testing athletes on the sideline during games and practices. With these advantages, Pison helps maintain a safe environment and protect the health of athletes of all ages.

For more information on Pison reaction time testing devices, or to get started with neural sensor and reaction time monitoring, visit www.pison.com.

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