Repetitive Head Impacts: A Major Concern At All Levels of Sports

Research now strongly suggests that CTE result of accumulation of undiagnosed subconcussive head trauma

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 <https://www.momsteam.com/sub-concussive/sub-concussive-hits-growing-concern-in-youth-sports?page=0%2C3>

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**UPDATED**

Brain trauma among football players (and athletes in other sports such as soccer and ice hockey) may be less the result of violent collisions that cause concussions as the cumulative effect of repetitive head impacts (RHI).  The discovery has led to increased calls by experts to take steps at all levels of sports, from professional down to the youth level, to limit exposure to such repetitive trauma, while a shrinking minority (including the NCAA) continue to urge a more cautious approach until more is known.

Although scientists have long suspected that RHI caused brain damage, especially in boxers, a [2010 study of high school football players](https://www.momsteam.com/health-safety/purdue-study-first-find-subtle-cognitive-deficits-in-high-school-football-players-from-repetitive-head-impacts) by researchers at Purdue University**[1,13]** was the first to identify a completely unexpected and previously unknown category of players who, though they displayed no clinically-observable [signs of concussion](https://www.momsteam.com/node/149), were found to have measurable impairment of neurocognitive function (primarily visual working memory) on [computerized neurocognitive tests](https://www.momsteam.com/node/801), as well as altered activation in neurophysiologic function on sophisticated brain imaging tests (fMRI).

Indeed, researchers found, the players with the most impaired visual memory skills were not those in who had been diagnosed with concussions but were in the group which, in the preceding week, had experienced a large number of RHI - around 150 hits - mostly in the 40 to 80 g range of linear acceleration.

**Shock-waves**

Publication of the Purdue study sent shock-waves reverberating through the football world, with the findings cited by concussion experts calling on youth sports organizations to take more aggressive action to minimize exposure to RHI, including sub-concussive blows, by changing the way contact and collision sports are played and practiced, and reducing the amount of brain trauma a child incurs by [limiting the number of hits](https://www.momsteam.com/node/4406) they sustain in a sports season, over the course of a year, and during a career.

Pop Warner responded by instituting [rule changes](http://www.popwarner.com/About_Us/Pop_Warner_News/Rule_Changes_Regarding_Practice___Concussion_Prevention_s1_p3977.htm) in 2012 designed to limit contact during practices.

In 2013, state high school athletic associations in [Arizona](http://www.prweb.com/releases/2013/4/prweb10637189.htm), [Washington State](http://www.bellevuereporter.com/sports/204181201.html), Iowa, and [Texas](http://www.dallasnews.com/sports/high-schools/headlines/20130421-uil-committee-recommendation-limits-in-season-full-contact-high-school-football-practice.ece) moved to impose some limits on full-contact practices.

In June 2013, the [Pac-12 announced](http://www.usatoday.com/story/sports/ncaaf/2013/06/03/pac-12-limiting-contact-football/2384731/) that it would adopt a policy limiting full-contact practices as well, although it did not state what those limits would be, only that they would be less than allowed by the NCAA.  The next month, the conference announced that the limit would be two a week, the same as the [Ivy League](https://www.momsteam.com/health-safety/rules-to-reduce-concussions-subconcussive-hits-in-place-for-2011-ivy-league-football) put in place before the 2011 season.  No other major college football conference has followed suit, at least so far.

In July 2014, the [NCAA issued new guidelines](http://www.ncaa.org/health-and-safety/football-practice-guidelines) recommending that full-contact practices during the season be limited to two per week. The NCAA guidelines also recommend no more than four contact practices per week during the preseason and no more than eight of the 15 sessions during spring football.

That same month California Governor Jerry Brown signed into law [AB 2127](http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB2127), limiting middle and high school to two full-contact practices - each no more than 90 minutes long - per a week during the 30 day period before the regular season and during the regular season itself, and banning off-season contact practices completely.

In advance of the 2014 season, the Wisconsin Interscholastic Athletic Association mandated new limits on the amount and duration of full-contact activities during team practices, prohibiting full contact during the first week of practice, limiting full contact to 75 minutes per week during week 2, and capping it at 60 minutes thereafter.

In November 2014, the National Federation of State High School Associations (NFHS) [recommended](https://www.momsteam.com/health-safety/nfhs-approves-concussion-task-force-recommendations-discussion-with-state-associations) to its member associations that they adopt limits on full-contact practices in high school football. The recommendations, contained in a [position paper](http://www.nfhs.org/media/1014079/2014-nfhs-recommendations-and-guidelines-for-minimizing-head-impact-final-october-2014.pdf) issued by the NFHS Concussion Summit Task Force in July 2014,**[42]** were  approved by the NFHS Sports Medicine Advisory Committee and the NFHS Board of Directors, and discussed by the 51-member state associations at the NFHS Winter Meeting in early January 2015.

n the months leading up to the 2015 fall season, some state associations adopted the NFHS recommendations exactly, while others altered them to more closely fit the needs of their member schools:

The state associations in Iowa, Kansas, Georgia and Tennessee opted to limit full-contact practice to 90 minutes a week.

Other states, such as Ohio, chose to limit full-contact to 60 minutes a week instead.

The Kansas State High School Activities Association (KSHSAA) was one of many state associations to make proactively make changes to its football rules that went *beyond* the recommendations of the NFHS Task Force. For example, players in Kansas are no longer be able to participate in "Live Action" the day after a game. And, effective with the 2016 season, they will not be allowed to participate in games on consecutive days, a change was made to address the issue of student-athletes playing a varsity game followed by a junior varsity game the next day.

Many states have also enacted rules changes establishing a progression up to full-contact in preseason practices, similar to the [heat acclimatization schedules](https://www.momsteam.com/health-safety/pre-season-heat-acclimatization-guidelines) integrated into preseason workouts in recent years. For example, the Illinois High School Association (IHSA) limits equipment to helmets only during the first two days of practice, helmets and shoulder pads the next three days, with full pads only being introduced on the sixth day of the acclimatization period. Similar progressions have also been adopted in Alabama, Minnesota and Kansas, among others.

**Gradual increase in contact in preseason needed?**

Interestingly, a recent study by Purdue researchers provides support for such a progression. finding that cerebrovascular reactivity (CVR) - a measure of the ability of blood vessels in the brain to dilate to compensate for increased levels of carbon dioxide in the blood, such as occurring during exercise - was significantly reduced in almost all football athletes during the first six weeks of the contact season, findings which the researchers viewed as demonstrating that the onset of subconcussive blows had "at least a transient effect on the brain, but also suggest[ing] that the brain can adapt to [the contact] with an eventual return to baseline."

The researchers expressed concern that athletes may be at risk of incurring symptomatic injury during period their brains were trying to adapt to contact at the beginning of the season. Noting that in most states football teams typically switch from limited contact levels during the preseason to two practices a day, at least one of which includes contact, they expressed concern that, based on their findings, "the brain may not be able to adjust quickly to this change, leaving players at increased risk for injury" at the beginning of the football season. They thus suggested that it might be better for teams to increase the amount of contact more gradually to allow players' brains to adapt so as to reduce the risk of serious injury. This is what the new rules in Illinois, Alabama, Minnesota, and Kansas appear to address.  Whether they go far enough is another question.

Prompted by the NFHS Task Force recommendations, member state associations have been reviewing there policies concerning offseason football. In states such as Ohio and Illinois, there were already rules in place to limit contact during the offseason, with teams prevented from participating in full gear or in full-contact practices. Other states that previously had no restrictions in place for offseason football have begun to adhere to the NFHS task force's guidelines as well.

**Cause for concern**

Since publication of the first Purdue study, similar findings about the effects of RHI, both in the short- and medium-term, have been reported by researchers **[8,9,16,19,21,22,26,27,28, 29-38]**, with several of the studies finding changes which persisted for weeks and even months after a football season ended.

Summarizing the state of the research in 2015, a study by researchers at the University of Virginia **[29]** found that, in the short term, RHI has been "linked to increased susceptibility to concussion, decreased cognitive function, altered gray matter functional connectivity, and changes in white matter microstructure," and that, in the long term, "retired football players who have sustained high levels of subconcussive impact over their careers have been hypothesized to have an increased risk of developing neurodegenerative disorders, like amyotrophic lateral sclerosis [e.g. Lou Gehrig's disease], Alzheimer's disease, Parkinson's disease, and chronic traumatic encephalopathy (CTE)."

An August 2015 editorial in  the *British Journal of Sports Medicine*, **[41]** said that autopsy studies - many conducted in Boston at the Center for the Study of Chronic Traumatic Encephalopathy - and a study reporting that retired NFL players who began playing football before age 12 demonstrated greater levels of cognitive impairment in their 40s-60s than those who started later, **[40]**   "raises concern that an accumulation of undiagnosed subconcussive head trauma may lead to (or be a leading factor) for CTE."

In a 2012 study,**[8]** researchers at the University of Rochester Medical Center (URMC) measured before-and-after data from the brains of a group of nine high school football and hockey players using an advanced form of imaging similar to an MRI called diffusion tensor imaging (DTI).  They found subtle evidence of axonal injury at the cellular level in six athletes who had not been diagnosed with concussion but sustained RHI during the normal course of play.  The abnormalities disclosed on post-season DTI scans among the players were closer to the scan of the one player with diagnosed concussion than to the normal brains in the control group. Axons, which are like cables woven throughout brain tissue, swell up when traumatic brain injury occurs.

The imaging changes also strongly correlated with the number of head hits (self-reported by the athletes in a diary), the symptoms experienced, and independent cognitive tests, said lead author Jeffrey Bazarian, M.D., M.P.H., associate professor of Emergency Medicine at URMC.

Another 2012 study **[19]**found that new learning on a sophisticated pencil-and-paper neurocognitive test declined over a single season of RHIs among college football and hockey players who did not experience concussions.  The study found that the players had poorer post-season reaction time and scores on a test of visual attention and task switching, which deficits were associated with greater head impact exposures.

Using DTI imaging technique, researchers at Indiana University School of Medicine and the Geisel School of Medicine at Dartmouth College, found in a 2013 study **[16]**significant differences in brain white matter of varsity football and hockey players compared with a group of non-contact-sport athletes, with the number of times they were hit correlated with changes in the white matter. They also found that some of the athletes, none of whom suffered diagnosed concussions, didn't do as well as predicted on tests of learning and memory at the end of the season, although the study did *not* find "large-scale, systemic differences" in the brain scan measures, which the authors found "somewhat reassuring" and consistent with the fact that millions of athletes play contact sports for many years [without developing progressive neurodegenerative disorders](https://www.momsteam.com/node/6773).**[17,18]**

Another 2013 study by researchers at URMC and the Cleveland Clinic **[9]** also found evidence of brain damage in college football players from RHI in the form of elevated levels of S100B, a protein in the blood usually present only in the brain. The presence of the S100B protein triggers the release by the body of antibodies which can then leak back into the brain through the damaged blood-brain barrier, where they are thought to attack brain tissue.  The highest protein levels were found among players who sustained the most hits to the head during games and practices.

Using DTI, researchers at Wake Forest found in a 2014 study **[26]**that a single season of high school football can produce changes in the white matter of the brain of the type previously associated with mTBI in the absence of a clinical diagnosis of concussion, and that these impact-related changes in the brain are strongly associated with a postseason change in the verbal memory composite score from baseline on the ImPACT neurocognitive test.  "Taken together, these data add to the growing body of literature providing evidence that a season of play in a contact sport can show brain changes in the absence of concussion or clinical findings," they wrote.

In a research paper presented at the annual meeting of the Radiological Society of North America in December 2014 analyzing the same data,**[27,28]** the Wake Forest researchers found that players experiencing greater levels of RHI (heavy hitters) had more changes to specific areas of their brains compared to players with lower impact exposure (light hitters).

There are also emerging data that football players are more frequently diagnosed with sport-related concussion on days with increased frequency and higher magnitude of head impact (greater than 100g linear acceleration).**(43-45)**

**Research continues at Purdue**

More recently, a remarkable [series of eight studies](http://www.purdue.edu/newsroom/releases/2015/Q3/deviant-brain-metabolism-found-in-high-school-football-players.html) **[31-38]**by Purdue scientists as part of an ongoing study of brain changes in high school football players, made a host of significant findings:

* the number of head impacts was related to substantive neurophysiological changes during the course of a football season, with all players sustaining more than 500 cumulative head impacts "flagged" for scoring more poorly on at least one component of the ImPACT neurocognitive test compared to their baseline, and/or displaying a statistically significant difference between pre- and post-season fMRI scans on 11 or more of 116 "regions of interest" in the brain;**[31]**
* high magnitude hits (over 60 g's of linear force) players accrued over the course of a season were more likely to prompt abnormal biochemical/metabolic responses in regions of the brain responsible for executive and motor function, with abnormal increases in metabolites sometimes followed by metabolic *decreases*, all dependent on the timing, number, magnitude, and location of blows to the helmet. The findings led the researchers to conclude that, with such "diverse metabolic consequences to accumulating sub-concussive blows, such competing mechanisms could (1) lead to no noticeable differences in overall metabolic levels and (2) ultimately mask symptoms in injured athletes," and provided "further evidence for a cumulative effect of head blows on neural health."**[32]**
* players who sustained more than 900 hits over the course of a season were much more likely than players hit less than 600 times in a season to be flagged by ImPACT, fMRI, or both.**[33]**
* players who averaged more than 50 head impacts per week (coincidentally, the typical number of plays a high school football offense or defense ran in a game) were flagged at a rate of 83% while those who received less than 50 hits per week were only flagged 43% of the time, a threshold the researchers considered significant.**[33]**
* when tested between 2 and 5 months after the football season ended, 6 out of 10 players had results which were flagged as abnormal, 11 by ImPACT, 12 by fMRI, with 3 flagged by both.**[33]** The findings led the researchers to conclude that using a neurocognitive test such as ImPACT, more commonly used by clinicians in measuring the effects of concussion and assisting in making return to play decisions, in combination with fMRI, which is sensitive to more subtle changes in brain physiology that may not be exhibited in cognitive performance, may provide a better assessments of a player's brain health than either measure by itself.
* where on the helmet a player was hit most rather than the number of hits was the best predictor of changes in the brain, suggesting that a player's style of play may be particularly important in determining brain changes resulting from subconcussive impacts.**[34]**
* abnormal brain activation patterns while players performed tasks involving visual working memory appeared to be related to exposure to contact: after several months of play, the players exhibited a high rate of deviation from their respective pre-season measures of brain activation, with the amount of abnormal activity increasing during the primary months of contact (August-October), only beginning to drop more than two months after the season ended (October/November), and not returning to baseline again until February-April. **[35]**    they said, as it suggested that, "even at sub-concussive levels of head impacts, there is neural reorganization and no true return to 'normal,' which, in turn, suggests that neural plasticity could be acting as a compensatory mechanism to keep football players asymptomatic."   As Thomas Talavage, a professor of electrical and computer engineering and biomedical engineering and co-director of the Purdue MRI facility, told *Purdue News****,*[11]** "The brain is pretty amazing at covering up a lot of changes. Some of these kids have no outward symptoms, but we can see their brains have rewired themselves to skp around the parts that are affected."
* athletes exposed to RHI exhibited significant abnormalities in the white matter of the brain during the season which increased as the season wore on, and persisted after the season. **[38]**Interestingly, the data suggested that the greater number of lesser intensity collisions experienced by the members of one football team resulted in injury at the cellular level (inflammation of the axons, which are like cables woven throughout brain tissue), while a lesser number of high intensity collisions experienced by the second team may have been more injurious to the fiber structure of the brain.  While the researchers said it was an "open question" whether one or the other may be of more clinical significance, the bottom line was the same: that the injury to the white matter of the brain was "slowly accumulating, with magnitude and number of events affecting the nature of the observed changes."

In the end, what the Purdue scientists found was that "concussed and non-concussed athletes look awfully similar, but that both look quite different from those who are not exposed to repetitive head collisions," said Talavage.

**Changes to brain persist**

Perhaps most concerning, four of the Purdue studies found that damage to the brain from RHI persisted after the football season was over, as did a 2014 study by Bazarian and his URMC colleagues, **[23]** which found changes in brain white matter in a small group of college football players which persisted six months after the season was over. They found a strong correlation between the white matter changes and the number of head hits with a peak rotational acceleration exceeding 4500 rad/sec2 and the number of head hits with a peak rotational acceleration exceeding 6,000 rad/sec2, and an especially strong correlation where the number of the former exceeded 30-40 for the season, and the number of the latter exceeded 10-15 for the season. (For reference, a person nodding his head up and down as fast as possible produces a rotational acceleration of approximately 180 rads/sec2).

That six months off may not be long enough for the brains of football players to completely heal after a single season, putting them at even greater risk of head injury the next season, was concerning, said Bazarian.

"I don't want to be an alarmist, but this is something to be concerned about.  At this point we don't know the implications, but there is a valid concern that six months of no-contact rest may not be enough for some players," he said. "And the reality of high school, college and professional athletics is that most players don't actually rest during the off-season. They continue to train and push themselves and prepare for the next season."

**Troubling findings**

The findings of the first Purdue study alone were troubling, said Larry J. Leverenz, PhD, ATC, a Clinical Professor in the school's Department of Health and Kinesiology, shortly after the study was published, because it meant that players were:

1. **Escaping detection.** Because they have not suffered damage to areas of the brain associated with language and auditory processing, they are unlikely to exhibit [clinical signs](https://www.momsteam.com/node/149) of head injury (such as headache or dizziness), or show impairment on [sideline assessment for concussion](https://www.momsteam.com/node/4002), all of which test for verbal, not visual memory, Leverenz said that "there is no way right now to identify" the group suffering sub-concussive blows to the head that may be dangerous.  Hence, they will likely continue participating in football-related activities, even when changes in brain physiology are present, which studies show likely increases the risk of future neurologic injury;
2. **Didn't know they were injured.**  If working memory deficits are sufficiently small, a player may not be aware of the additional effort required to complete everyday tasks, and therefore not think to bring the problem to anyone's attention (although at least one of the players in the impaired group seemed to have figured this out, and played with better, [heads-up technique](https://www.momsteam.com/node/2839) the next season, reducing the number of hits he took to the forehead); and
3. **Facing an uncertain future.**  Even though the players in the original  Purdue study who suffered short-term cognitive impairment from repeated sub-concussive blows exhibited results on fMRI and ImPACT tests administered before season #2 comparable to the baseline results before season #1, their return to baseline did not necessarily mean that there was 100% recovery, as several of the subsequent Purdue studies demonstrated. It is possible that the damage will only be known over the long term, years later.

Commenting at the time on the 2010 Purdue study for [*Sports Illustrated*](http://sportsillustrated.cnn.com/vault/article/magazine/MAG1176377/index.htm)  **[15]**, Randall Benson, a neurologist at Wayne State University in Detroit, speculated that the Purdue researchers may have taken what amounted to a "real-time snapshot" of the early stages of the corrosive creep that wears away at the frontal lobe, a part of the brain involved in navigating social situations. Too much erosion and victims reach a breaking point - like former Steelers offensive lineman Terry Long, who died in 2005 from drinking antifreeze. "It's an insidious progression," Benson said, "and it's not obvious when you talk to [players]."

Four years later, Benson's speculation was echoed in eerily similar comments by Bazarian and his colleagues in the 2014 URMC study: "[i]f RHIs are related to neurodegeneration many years later, a long clinically silent period between the onset of neuronal injury and overt symptoms of dementia would not be unexpected." During this clinically silent period, however, there may be indicators of dysfunction on a cellular level, such as the elevated levels of S100B antibody found in the cerebral spinal fluid in the football players in the study, even six months after the end of the season, which he said, could "potentially herald the early stages of [chronic traumatic encephalopathy] or CTE."

"Pending confirmation in a long term longitudinal study tracking athletes prospectively for years to decades looking for manifestations of early cognitive dysfunction and dementia," writes Bazarian, "we believe our results suggest that these persistent DTI changes are likely detrimental.  If borne out in future research, the long-term persistence of these [white matter] changes would mean that athletes returning to play the following season would be at risk for expanded RHI-related WM changes, undetectable by conventional assessments. Could the lack of WM recovery we observed result in cumulative WM damage with subsequent football seasons of RHI exposures? If so, could this cumulative WM damage be related to the long-term development of CTE?"

Commenting on the recent series of Purdue studies for *Purdue News*,**[30]** Eric Nauman, a professor of mechanical engineering, basic medical sciences and biomedical engineering, and author or co-author of all 10 of the Purdue studies, said he was "particularly disturbed that when you get to the offseason, - we are looking somewhere between two and four months after the season has ended - the majority of players are still showing that they had not fully recovered."

# Is better detection the answer?

One approach to the problem of sub-concussive blows that escape detection via conventional means is to find new enhanced detection methods: If functional impairment could be detected on the sports sideline, a player, like those exhibiting more obvious concussion signs or complaining of symptoms consistent with concussion, could be removed from play.

As Dr. Leverenz told MomsTEAM after publication of the first Purdue study, the limitation of screening tools currently being used to assess neurocognitive function on the sports sideline, such as the [Standardized Assessment of Concussion (SAC)](https://www.momsteam.com/node/215) and the [Sports Concussion Assessment Tool 3 (SCAT3)](https://www.momsteam.com/node/1335), is that they test *verbal* memory, not the visual memory which he and the Purdue researchers found impaired in the functionally, but not clinically impaired, players who experienced at least short-term neurologic trauma from RHI.

All too often, even hits hard enough to cause an athlete to display signs of concussion that can be observed by sideline personnel, or which cause the athlete to experience symptoms of concussion, go undetected, either because the signs are too subtle to be seen or are simply missed by sideline personnel or because the athlete fails to report them (a 2010 study**[7]** of Canadian junior hockey players, for example, found that, for every concussion self-reported by the players or identified by the coaches or on-the-bench medical personnel, physician observers in the stands picked up *seven*) - a persistent problem that, given the "warrior" mentality and culture of contact and collision sports, is not going to go away any time soon, if ever.

One way to increase the chances of detection may be to equip players with impact [sensors](https://www.momsteam.com/node/4120) to alert sideline personnel to head impact exposure, either from a single, forceful hit, or from less forceful but repetitive blows, that has the potential to result in brain injury, which could help medical staff identify athletes who should be removed for evaluation on the sports sideline and, if found to have a suspected brain injury, referred for further evaluation and banned from a return to play.**[6]**

# Are reducing full-contact limits or hit counts a solution?

But better detection does nothing to prevent such brain trauma, or at least reduce the risk, in the first place.  No matter how good the technology, no matter how good we get at identifying suspected concussions, the essential problem remains: the hits themselves.

As a result, an increasing number of experts are urging that the focus be on reducing the risk of concussions and sub-concussive brain trauma by [reducing exposure to concussive and sub-concussive hits](https://www.momsteam.com/node/4679) that athletes sustain during contact and collision sports.

Limiting contact practices in football to one session per week, or eliminating contact practices altogether, for example, would, according to a 2013 study**[10]** by researchers at the University of Michigan, result in an 18% to 40% reduction in head impacts respectively over the course of a high school football season.

The Michigan study pointed to recent research suggesting that the number of head impacts sustained may play a more important role in putting an athlete at risk of developing CTE than clinically evident concussions.  Among them were the Purdue and Rochester studies of athletes in high school and college football**[1,8,9,12,13, 31-38]** and ice hockey, **[8]**which, as noted above, found subtle changes in cerebral function in the absence of concussion symptoms or clinically measurable cognitive impairment which researchers linked to the volume of head impacts, and a much publicized case-study autopsy of a collegiate football player, Owen Thomas, with no reported history of concussions, which revealed early signs of CTE.**[14]**

"If verified," lead author, Steven P. Broglio, PhD, ATC, of Michigan NeuroSport and Director of the NeuroSport Research Laboratory at the University of Michigan, writes, these reports "would support the use of head impact numbers to limit the head trauma volume experienced by an athlete each season."

Broglio recognized that "contact sport athletes appear to be at a greater risk for developing CTE,"  but was careful to note the absence of studies "indicating the relationship between head impacts, concussions, and other factors (eg. genetic profile) that may trigger the disease pathway."

He described the goal of reducing the overall number of head impacts that high school football players sustain in a season as "logical" and "appealing," but noted that, "until the risk factors for [chronic traumatic encephalopathy](https://www.momsteam.com/node/3289) (CTE) are better defined by carefully designed and controlled research," and research determines "what the advisable limit to head impact exposure should be," employing contact limits or establishing "[hit counts](https://www.momsteam.com/node/4406)" will remain "educated guesses, at best."

Indeed, the 2014 University of Rochester study **[23]** suggests that, "rather than monitor total head hits, as [was initially suggested [by Sports Legacy Institute in its much publicized Hit Count program], it may be more effective to monitor those hits that are most likely to produce [white matter] changes, which Bazarian and his colleagues found were when the number of helmet impacts resulting in a peak rotational acceleration of 4500 rads/sec2exceeded 30-40 for the season, and when the number of helmet impacts resulting in a peak rotational acceleration .6000 rads/sec2 exceeded 10-15 for the season.

Two of the Purdue studies **[36,37]** suggested that it might be possible to reduce risk of brain trauma by gradually increasing the amount of contact in the football pre-season to allow time for players' brains to adjust, and one, by finding that players who sustained more than 50 hits per game, were much more likely than those who sustained fewer hits to be "flagged" by ImPACT and/or fMRI results as having neurocognitive deficits or altered brain activity, suggested that players be limited to a certain number of plays per game (a hard rule to implement, given the prevalence of two-way players in the high school game).

A 2016 study by Broglio **[46]**found that a rule change limiting full-contact high school football practices appears to have been effective in reducing head-impact exposure for all players, with the largest reduction occurring among lineman.  The study found that impacts were reduced from an average of 592 impacts per player per season before the rule change to an average of 345 impacts per player per season, or a 42% decline in impact exposure

Although Broglio and his colleagues viewed the results as "promising", they were careful to note that the restrictions on full-contact practices in football were being implemented despite a "lack of clarity surrounding the relationship between repeated head impacts in high school athletes and long-term neurocognitive dysfunction.

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# Question of balance

Finding a way to reconcile two competing demands - minimizing contact in practice in order to reduce the number of concussions sustained and the number of hits players sustain over the course of a week and a season that emerging science, now more than ever, suggests may have a [deleterious cumulative effect](https://www.momsteam.com/node/5481) on a player's cognitive function over the long term, while at the same time maximizing the amount of time in practice learning how to tackle and block without head-to-head contact - time that is needed to maximize the protective effect of proper tackling on the number of head-to-head hits players sustain in game action, which can not only result in concussion, but catastrophic neck and spine injuries - is challenging, but clearly not impossible.

"As a scientist, I am not in a position to make policy," Broglio told MomsTEAM, but "we can't just reduce [the number of contact practices] without looking at the whole picture. We don't know if 18% means anything, or how much less [in terms of the number of impacts] is meaningful."

If he were making policy, however, Broglio would "lean more towards the cautious side" in limiting contact practices, which is not to say that he doesn't think "that a football program could be successful" with some limits on full-speed contact practices.  Pointing to rugby, where players practice tackling without helmets without increased risk of head injury in games, he "didn't necessarily buy" the argument advanced by some experts that limiting contact practices would expose football players to increased injury risk in games.

As Broglio writes in his 2013 study, however, his view comes with a very important caveat: only if "extra emphasis on the appropriate tackling technique [is] put in place to ensure that the highest level of safety was maintained during games."

While the recent movement to limit full-contact practices is intended to make the game safer, some experts agree with Broglio that [caution should be the byword](https://www.momsteam.com/node/6041).  A March 2013 review of current risk-reduction strategies in the *British Journal of Sports Medicine* **[11]** reminds state high school athletic associations and legislatures that, in enacting rules, such as limits on full-contact practices, they "need to carefully consider potential injury 'trade-offs' associated with the implementation of injury-prevention strategies, because every change may have certain advantages and disadvantages. That is, by reducing one risk or danger, additional risks may be created." In other words, as the Michigan study points out, limits on full-contact practices could create additional risk of injury to players because they haven't spent enough time learning to tackle properly.

The results of at least two recent studies, however, suggest that reductions in full-contact practices *can* be accomplished safely without putting players at additional risk, while researchers continue looking for the head trauma "holy grail": a threshold - whether it is number of hits per week, over the course of the season, of a certain force, or to a certain part of the helmet  (e.g. facemask, top of the head) above which players are at an unacceptably high risk of permanent brain injury.

A[2013 study](https://www.momsteam.com/health-safety/sports-concussion-safety/concussions-by-numbers/head-hits-can-be-reduced-in-youth-football-study-says) by researchers at Wake Forest Baptist Hospital and Virginia Tech **[24]** showed that reducing the number of head hits in practice did not, as [some had predicted](https://www.momsteam.com/health-safety/youth-football-concussion-study-generates-controversy-over-suggestion-that-limiting-contact-practices-mistake) **[25]**lead to higher force impacts during games.

And, more recently, a 2015 study [39] reported that comprehensive coach education in teaching "heads up" tackling and practice contact restrictions, such as implemented by Pop Warner, can be effective in reducing the rate of concussions in youth football.

The challenge is to determine whether a critical number of head hits exists above which this type of brain injury appears, and then to get players and coaches to agree to limit play when an athlete approached that number.

As the recent Purdue studies demonstrate, science is coming closer than ever before to determining that number,

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