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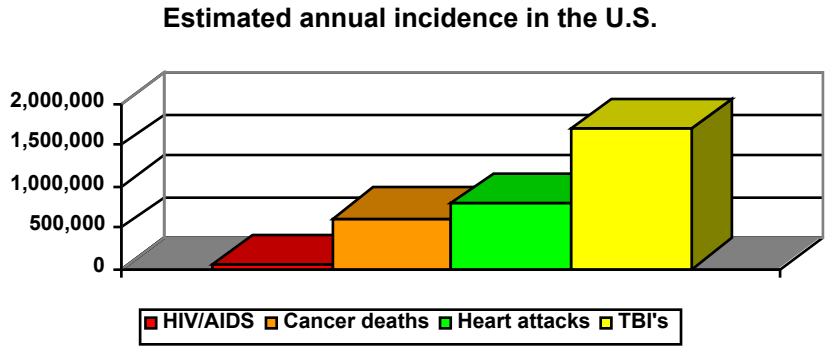
Traumatic Brain Injuries, Concussions & Sub-concussions

"*No head injury is too severe to despair of, nor too trivial to ignore.*"
--Hippocrates

DISCLAIMER: the following is not meant to treat anyone with advice or tell you what you should do, such as relative to use of medication, exercise, or changing your diet. The information in this handout is merely offering what has been published in the research literature, as well as based on my professional experience. Talk to a doctor or other appropriate professionals as to what is best for your own specific needs.

It should also be appreciated that everyone has their own perspective on how to improve health. Nutritionists do it through food. Physicians do it through medicine. Psychologists do it through changing thoughts, feelings, and behaviors. Consequently, what is offered here is a reflection of my own bias and perspective.

Traumatic brain injuries (TBI's, also often referred to as a head injury, or HI) have been called 'the silent epidemic' in the U.S. Estimates vary as to how many occur in this country every year, but as of 2013 the CDC estimated around 1.7 million, and this does not include most concussions, many of which never get diagnosed as such. The majority of those TBIs that occur are milder in degree. But, 52,000 people every year die from concussions, and 275,000 need to be hospitalized over them. And as the quote above suggests, minor head injuries may be a contradiction in terms. That is, damage to the brain is never good.



The ratio of male/female ratio of TBI's is generally estimated as being somewhere between 2:1 and 3:1. The risk of TBI is greatest in the 0-4, and 15-25 year old age groups. Recent research by the CDC have found that TBI's leading to trips to the Emergency Room are due (in decreasing order) to:

- falls
- being struck by or against

- motor vehicle traffic
- assault
- 'other'
- and 'unknown'

Sports-related TBI's used to be thought of as being a small issue, but recent attention to concussions resulting from sports contact, and permanent damage being done all too often, is changing that perception. The problem is that many sports concussions and possibly cases of permanent brain damage resulting are never diagnosed. There are an estimated 3.8 million sports- and recreation related concussions in the U.S. every year. But figuring out if any particular athlete has 'just been hit' vs. 'suffered a concussion' be it minor or serious, can be the difficult part.

The wars in Iraq and Afghanistan are another recent source of many TBI's, which can include what has been called persistent post-concussion syndrome (PPCS, meaning concussion symptoms that are lasting longer than expected such as measured in weeks, months or years), and the estimated number offered above does not include returning vets. And again, many vets may not be recognized as having PPCS.

Some Basics

TBI's can be classified in a variety of ways. One is whether they are 'open' (OHI) or 'closed' (CHI). Open head injuries are easy to explain – the skull has been cracked, penetrated, or otherwise physically broken. They can occur from blows such as a person's head hitting a windshield, or something striking the head like a baseball bat. Bullet wounds to the skull are another obvious example of an open head injury.

Closed head injuries are the opposite – there has been no cracking or penetration through the skull. These too can arise from a variety of means. Motor vehicle accidents (MVA's) are the primary means for both open and closed head injuries to occur. Other means to sustain a closed head injury may not involve 'trauma' per se – such as from drowning, or other forms of oxygen deprivation (e.g. carbon monoxide poisoning, heart attacks). Falls (such as down stairs, off a ladder, or a bike), and assaults/fights are other common means to a closed head injury.

All things being equal, CHI's result in more brain damage than open head injuries. This may seem paradoxical. But, the reason for this is that if the skull fractures it is absorbing some amount of energy and so less is received by the brain itself. If the skull remains intact, all of the energy from the traumatic blow is transferred inside to the brain where it can cause more damage. The simple way to understand this is that in a car accident it is better for a vehicle to crumple up – and absorb some of the energy – than for it to be too rigid and have that force transferred to inside the passenger compartment. This is why modern vehicle design involves crumple zones so that the metal takes the brunt of the force and not the passengers.

A second means to classify TBI's is by their severity. The four most common labels used are minimal, mild, moderate and severe. The terms may be easy to understand on an abstract level, but are far harder to apply on an individual level.

The best way to understand what these terms mean is to start with the ones that are easy to agree on: 'minimal' and 'severe.' Minimal brain injuries are what I call 'little dinks.' They can occur in any number of ways, like someone working under the kitchen sink on the plumbing. When they

move to get up their head can bang into the cabinet. A small percentage of people who bang their head in such a manner may ‘see stars’ or get a little headache for a few seconds. Other types of little dinks may include people who fall down or on to something, and get a temporary goose egg on their forehead in terms of some edema forming under the skin.

Such minimal blows to the head may be transmitting some force to the brain, but in my experience the probability of permanent brain damage having occurred is between little and none.

Severe brain injuries are also easy to recognize. Anything that puts a person in to a coma for some amount of time would be an obvious example. Or, anything that suddenly transforms a person’s life and puts them in to a permanently disabled state, such as no longer being able to walk or talk, is almost undoubtedly going to be a severe brain injury.

That leaves ‘mild’ and ‘moderate’ to define and recognize. Various professionals and organizations have come up with different definitions for mild TBI’s. I do not like any of them because of their having too many inherent flaws. For instance, most require that a concussion be diagnosed and that it not last beyond a certain number of minutes. The flaw in this part of such a definition is that many people never receive medical attention at all. Or, they go to a doctor or hospital and the treating physician misses the presence of a concussion even though one has occurred.

Consequently, the way I conceive of ‘mild’ TBIs (mTBI) is different. And that is if a person’s ability to function normally is adversely affected by such a blow, and they return to (near) normal ability within about three months. One example of ‘return to seemingly normal function’ in short order is with sports-related concussions. High school and college athletes may sit out of a game for a minute, a quarter, the rest of the game, or even a few days or weeks. But, at some point they go back to play and are thought to be fully normal.

Other examples of mTBI can include someone having temporary headaches that have resulted from a blow to the head and which interfere with their daily living, such as handling school or work functions. Or, they may have some problems with finding the right word when they talk for a week or two. Or, their short term memory is not as sharp for awhile. Personality changes, such as being more depressed, withdrawn, or irritable can occur for awhile.

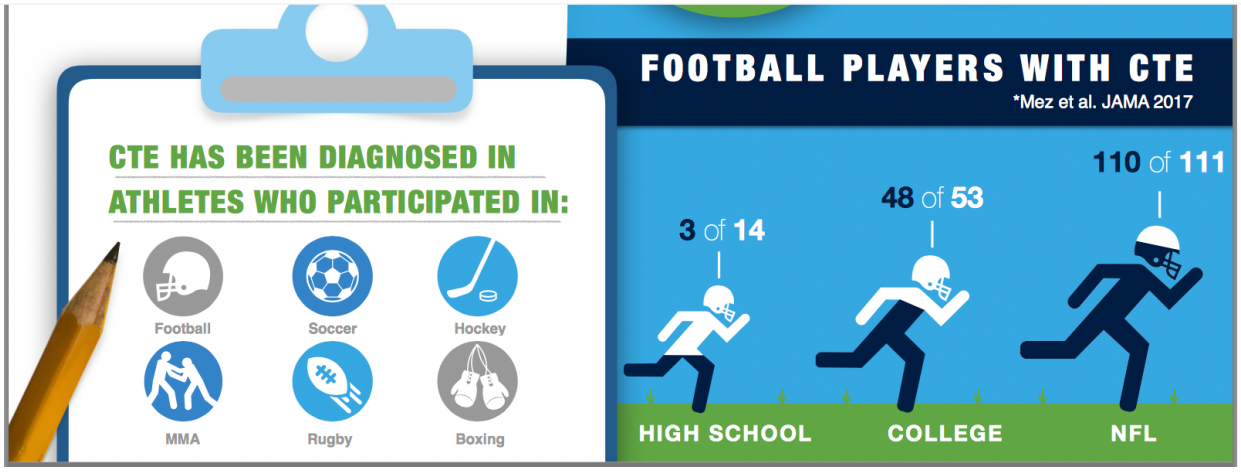
Another way I think of mTBIs is that they are most likely the brain injured people who never know they have suffered damage. This is the group of people that I see most frequently, and their numbers are very large.

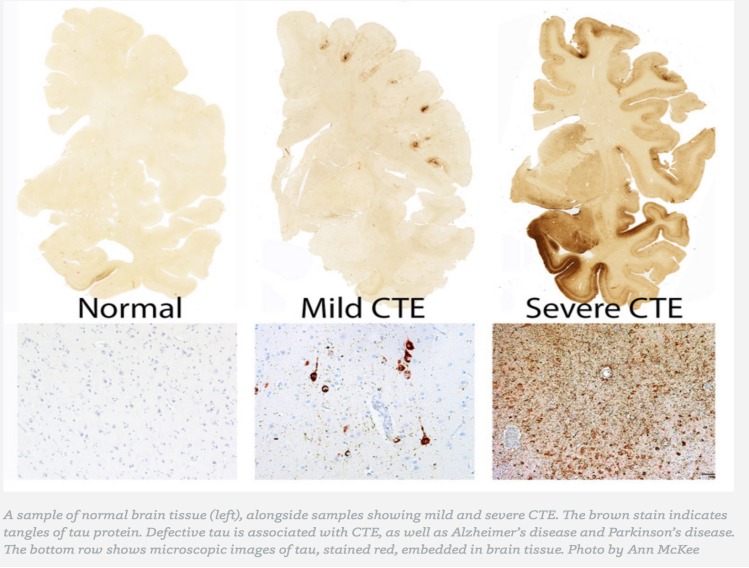
What is a ‘moderate’ TBI? Not mild, and not severe.

Again, formal professional definitions do exist for a moderate brain injury, but I have not found them any more practical than the ones for ‘mild.’ Offering such a classification scheme for a brain injury is murky. It can be likened to trying to classify different shades of gray: light, medium-light, medium, medium dark... Where does one end and the next begin? Try and get a group of people to agree. This is the problem with trying to classify ‘mild’ or ‘moderate’ or ‘mild-to-moderate’ TBI’s. Rather than obsessing over the exact label that is applied, I am more concerned about what the effects are on a person and their ability to live their life in an effective manner.

Blows to the head can be cumulative so two or more little ones may equal one larger one. There has been recent attention to concussions causing permanent brain damage due to NFL football players being diagnosed with TBI and in some cases dying very early deaths from what is called chronic traumatic encephalopathy (CTE). CTE is caused by repeated impacts, and can be found in athletes, those with head trauma from other occupations such as the military, and people with seizures and/or head banging behavior. It entails problems with memory, executive skills, mood and behavioral disturbances that can include depression, apathy, impulsivity, anger, irritability, suicidal behavior, and aggressiveness. Problems with movement that look like Parkinson's can also occur, and eventually there is a progression to dementia. The neuro degeneration is slow and mean survival time is eighteen years from the onset of symptoms.

CTE was initially named dementia pugilistica because of it being found in people who boxed. Muhammad Ali is probably the best known person who suffered from it. (It is estimated that he suffered 150,000 blows to his head over his boxing career.)





A sample of normal brain tissue (left), alongside samples showing mild and severe CTE. The brown stain indicates tangles of tau protein. Defective tau is associated with CTE, as well as Alzheimer's disease and Parkinson's disease. The bottom row shows microscopic images of tau, stained red, embedded in brain tissue. Photo by Ann McKee

This research on football players as to the above graphic, like all, is not without flaws. It was based on people donating their brain to science after their deaths. i.e. Donations may have been skewed by those players, or their families, who thought they were showing signs of CTE vs. football players who died without CTE symptoms perhaps being less likely to donate their brains to be autopsied after the fact. So that could throw off the percentages and make it look worse than it might be.
www.BU.edu.research "CTE found in 99% of former NFL football players studied" Barbara Moran

However, subsequent research from BU's School of Medicine that came out in Annals of Neurology in October 2019 then looked at that possibility, and it found that playing the game longer was the big risk factor. More specifically, they found that for each year of play increased

the odds of CTE developing by 30%. Plus, for those with CTE diagnosed the odds of having severe symptoms of it doubled for every additional 5.3 years of football played. Those who played 4.5 years or less of tackle football had one-tenth the risk of CTE than those who played it longer. However, some players with under four years of play still developed CTE. Those playing more than 14.5 years were ten times more likely to develop CTE than those who played less. But again, several players with 15+ years were not diagnosed with it.

The 2019 BU research also looked at total number of concussions, positions played, the player's first age of playing tackle football, other contact sports they may have played, race, and the presence of other diseases to see if these factors were related to CTE. And no associations were found.

There was other research that looked at 246 tackle football players after their deaths and who donated their brains to such research, with 211 being diagnosed with CTE. For every year sooner that they started to play tackle football cognitive and behavioral/mood symptom onset began about 2 ½ years earlier. Being exposed to tackle football prior to the age of 12 predicted earlier cognitive and behavioral/mood symptom onset by about 13 ¼ years. Conclusions included that "youth exposure to tackle football may reduce resiliency to late-life neuropathology." (Annals of Neurology, "Age of first exposure to tackle football and chronic traumatic encephalopathy" Michael Alosco et al, May 2018).

It should also be appreciated that any sport, not just football, can lead to concussions or TBIs. Boxing has the highest. Contact sports like football, ice hockey and rugby are the worst for males getting concussions. With women, soccer is consistently the worst.

Concussions in kids such as in middle school years may also heal at one-fourth the rate that they do in adults. So there is an opportunity for kids to have second impact syndrome occur, where one concussion occurs on top of a prior one, and damage gets exacerbated as a result. Some research has found that 41% of concussed high school kids returned to action on the field before their brain had time to recover, so this issue is not just theoretical.

Sport	Concussion rate per 100K athletic exposures*
Football	64-76.8
Boys' ice hockey	54
Girls' soccer	33
Boys' lacrosse	40-46.6
Girls lacrosse	31-35
Boys' soccer	19-19.2
Boys' wrestling	22-23.9
Girls' basketball	18.6-21
Girls' softball	16-16.3
Boys' basketball	16-21.2
Girls' field hockey	22-24.9
Cheerleading	6-8.6
Girls' volleyball	6-8.6
Boys baseball	4.6-5
Girls' gymnastics	7

http://www.headcasecompany.com/concussion_info/stats_on_concussions_sports

*Athletic exposure: one athlete participating in one organized high school athletic practice or competition, regardless of the amount of time played. The above numbers are one set of estimates, and others do not necessarily rank them in the exact same order. But it gives you an idea.

Then there are sub-concussions, which are blows to the head that do not create any *overt* symptoms. There has been research that sub-concussions can result in permanent brain damage. How? Think of a car hitting a big pothole at high speed and blowing out a tire, or breaking an axle. Metaphorically, that's a concussion or a TBI. Now imagine a car hitting smaller potholes where no immediate damage occurs. But drive over a pothole strewn road for years and it will do damage to your car, such as it developing rattles, or wearing out the shocks faster. The same is true for the brain: little invisible damage can add up over time.

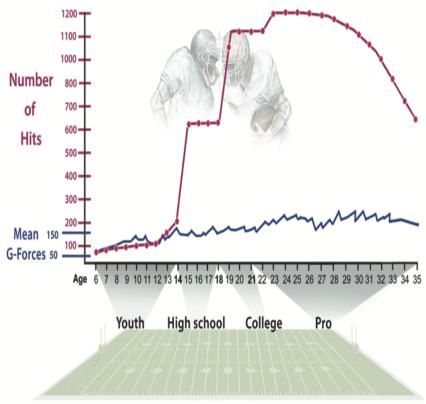


Fig. 2. Graph showing cranial impact exposure in football players of various ages. Biophysics data gathered through football helmet accelerometer studies have shown that youth, high school, and college players may experience a wide range of head impacts, from 100 to over 1000 during the course of a season. As compared with the location and magnitude of forces, the cumulative number of head impacts is likely to best correlate with the potential for concussion occurrence and/or long-standing effects and the development of neurodegenerative disease.

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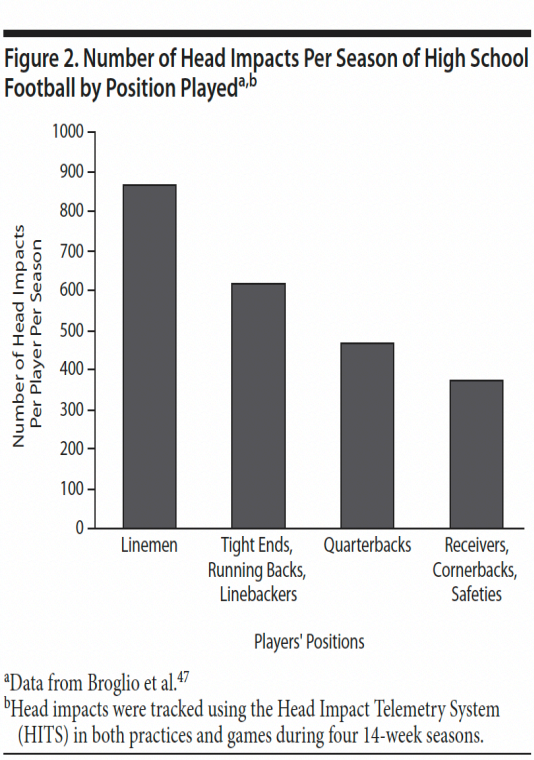
Julian Bales, above

Let's look at some real numbers based on research done on high school football players with sensors placed in their helmets (Journal of Neurotrauma, "Cumulative head impact burden in high school football", Oct. 2011, Steven Broglio et al.) Ninety-five players over four seasons were monitored.



The average player sustained 652 impacts – with a range of 5 to 2,235 during a season. Linemen had the greatest averaging 868, safeties the fewest at 372. College players sustained nearly 1500 hits per season, according to this research. The research also found that linemen incur impacts of 20-30 g's on *nearly every play* which would translate to 45-55 times/game. Adolescent hockey players were cited as sustaining an average of 288 impacts/season. Soccer players in one study were found to head balls an average of 264 times/season. How many blows does it take to cause permanent damage from such impacts? No one knows for sure. But the graph above to the left suggests total hits may be the most important factor for what creates sub-concussive burden.

Igor Bastidas, below

Sub-concussive blows to the head can arise from more than football. Heading soccer balls is another prime example of how damage can slowly accrue over seasons and years. Soccer is the most popular participation sport in the world. A study done by Albert Einstein College of Medicine that came out in 2018 found that frequent ball heading is worse in causing cognitive impairment than unintentional head impacts (such as player to player, or player to goal post). It looked at 308 players, mostly male, between the ages of 18-55 over a two week period with an average of 45 headings occurring. Players with the most headings had the poorest performance on tests of psychomotor speed, working memory, and attention which are areas known to be impacted by brain injury. Unintentional head impacts had no correlation to cognitive impairment.

A study published in Neurology in 2017 looked at amateur soccer players who played the game at least six months a year in leagues or clubs, and how often they headed the ball in the prior two weeks. There were 222 players (79% male) in the study. Heading was divided into quartiles, with the highest frequency averaging 125 headers in the two weeks, and the lowest just four headers.

Central nervous symptoms (CNS) of head impacts like pain or dizziness were rated as 'moderate.' Being dazed was rated 'severe.' Being knocked out was 'very severe' CNS. Those with headers in the highest quartile were three times more likely to have symptoms than those in the lowest quartile. Two or more collisions and/or falls ('unintentional impacts') were six times more likely to have symptoms than those with none, with one such impact three times more likely to have symptoms. Another study found that 30% of soccer players had 1,000+ headings/year, and had a higher rate of micro damage to the structure of white matter in the brain (the nerves connecting different parts of the brain) which is typical of TBIs, along with worse cognitive performance.

A study done by Purdue University looked at women's soccer teams including two high school and one college level, as to monitoring G-forces of heading balls over a season, as well as brain MRIs to track changes in them. Heading a goal kick came in between 50-100 g's. "The percentages of 100g hits was effectively the same between women's college soccer and American football, which really surprised us" said Eric Naumann who is the director of Human Injury Research and Regenerative Technologies Lab at Purdue. "While American football players tend to take more hits overall in a given practice season and game, the college players were getting hit every day and so it evened out."

MRI scans of the brains show that brain injury is a concern. "We looked at how the blood vessels responded to these headers, and the players who were in the top half for hits taken you could see their vasculature was damaged" Naumann said. "These are things that can heal, but they need rest."

Car accidents as a comparison can generate considerable amount of g-forces too even while wearing a seat belt. For a 150 pound person consider the following

Vehicle speed	With/without seat belt g-force
25 MPH	32/ 159
35 MPH	64/ 312
50 MPH	127/ 637
70 MPH	250/1,248

A study published in Frontiers in Neurology in 2016 offers a hint but not conclusion on how many blows are needed to cause permanent damage. Research was done on former male professional soccer players, ages 39-68 and had them undergo brain scans. They looked at a measure of the integrity of white matter, the myelination (insulation on the nerves), and axonal density. They found thresholds needed to trigger a reduction in this measure, being between 885-1500 headings/year depending on the brain region, and cognitive impairment (1800 headings/year). Lifetime concussion history and demographic features did not explain the results. A limitation of this study is it does not prove causation between headings and brain changes, only an association or correlation.

Another study looked at 49 men and 49 women ages 18-50, with players of similar ages and heading frequency being compared between the genders. Women showed more white matter alterations than the men. Another study done in Puerto Rico on boys and girls ages 9-11 looked at how much g-force was generated by heading balls, and found it ranged between 16-60 g's. For adults, 60 g's is enough to cause a concussion, although none of the kids in the study were diagnosed with a concussion. The kids were tested within ten minutes after a game for cognitive

skills. A single heading during a game was enough to cause a slight drop in some skills. It was a short-term study and so whether permanent damage was done is not known from it.

A large Scottish study on soccer (JAMA Neurology, "Association of field position and career length with risk of neurodegenerative disease in male former professional soccer players" Emma Russell, et al, 8/2/2021) took 7,676 former professional soccer players and matched them against the general population for controls using birth year, sex, and socioeconomic status. They were followed for an average of 18 years. Average length of professional soccer was about 8½ years, spanning from about age 20-28. Goalies did not have a significantly increased risk of neurodegenerative disease such as dementia or Parkinson's. Outfield positions and especially those in the defender role, meaning those doing a lot of heading, had a 3.5 times higher rate of such disease, with the defenders being up at roughly a 5-fold greater risk. Goalies had about one-third the rate of such diseases compared to the outfield positions. Those with shorter careers had lower risk.

Cumulative hits such as from sports like football or soccer can affect memory and attention skills. Some of the damage that is done from sub-concussive impact is to the wiring of the brain meaning that different regions can not communicate as well with each other. In such cases people may notice their thinking is 'slow' or 'foggy.' There is also a concern that more sub-concussive hits may lead to problems later in life such as mood and behavior issues. Early research on the subject has found that athletes with more hits were at greater risk for mood and behavior problems later in life. But there has been insufficient time to do such research yet, given how recently this concern has been raised.

Other research (Scientific World Journal, "Biomechanics of heading a soccer ball: implications for player safety" F. Babbs, August 2001) note that heading a ball can be dangerous "depending on key characteristics of both the player and the ball. Safety is greatly improved when players head the ball with greater effective body mass, which is determined by a player's size, strength and technique. Smaller youth players, because of their lesser body mass, are more at risk of potentially dangerous headers than are adults, even when using current youth size balls. Lower ball inflation pressure reduces risk of dangerous head accelerations. Lower pressure balls also have greater 'touch' and 'playability,' measured in terms of contact time and contact area between foot and ball during a kick. …Avoidance of head contact with fast, rising balls kicked at close range can substantially reduce risk of subtle brain injury in players who head soccer balls."

There is also other effects of TBI's which surprisingly can impact other elements of our health. A study done by UCSD in 2009 on mice (Journal of Neurotrauma, "Traumatic Brain Injury and Intestinal Dysfunction: uncovering the neuro-enteric axis" Vishal Bansal et al, Aug. 2009) found that they cause 'leaky gut' as to intestinal permeability which permits bacteria and other toxins into the bloodstream that do not belong there. This can cause inflammation, poor digestion, fatigue and other symptoms. Other research done on football players in 2022 found that even a single concussion can disrupt the gut microbiome that may lead to inflammation (Brain, Behavior and Immunity – Health, "Alteration to the gut microbiome after sport-related concussion in a collegiate football players cohort: a pilot study" Sirena Soriano et al).

Risk factors for having concussions arise include most prominently a prior history of concussions, and being female. Younger kids may be more susceptible to concussions (meaning younger grade

school are more prone over high schoolers who are more prone over college kids). Wearing a helmet does not prevent concussions, but may prevent other injuries.

Looking for TBI's

Given my orientation, of caring less about the label of what degree injury may have occurred (mild or moderate TBI, concussion, sub-concussion), and focusing more on the effects and what might be done to treat them, I first have to determine if any TBI's have occurred. In obtaining background information during a neuropsychological assessment I ask a number of questions to see if the person may have received a TBI over the years, whether they know it or not. Such questions include:

- Have you ever been in a car accident?
- Have you been 'dinged' ('had your bell rung') while playing sports?
- Fallen off a bike, ladder, out of a tree, etc?
- Fallen down stairs?
- Been in physical fights?
- 'Seen stars' from having something hit you in the head?
- For anyone in the military, have you been exposed to concussive blasts which can include IED's, RPG's, mortars, grenades, or bombs? Or, had serious falls, such as from elevations like a high platform military vehicle?

The problem with such questions is trying to determine the seriousness of such an injury. For instance, many people report being in fender benders, and minimize and downplay the car accident. Was it a minor collision? I was not there, and so it is very difficult for me to determine the seriousness of it. How much speed was involved? Was the person wearing a seat belt? Did they have headaches, nausea, vomiting afterward? For how long? Were they dazed or woozy, and if so how long did it last? For those in the military, all too often they are required to continue to carry out their mission, and do not have time to get checked out appropriately, and so symptoms of concussions get overlooked. These types of questions lead once again to trying to classify the shades of gray, and so certainty is difficult to obtain.

One way I try to better determine what might have happened to a person – and if brain injury has occurred - is by focusing not on the incident ('It was a fender bender') but instead the number of these types of blows over the person's life time. The way I count brain injuries is: "one, two, three, too many to keep track of."

Why such a counting system? The common wisdom is that having a single TBI doubles the risk of having a second. If two have occurred, the risk of a third happening is eight times greater than normal. If three occur, in my experience the risk of having 'more than three' is unknown but very large. That is, head injury occurrences spin out of control, in a downward spiral. People with more than three will typically tell me that they know they have had several, but have long since forgotten the details of most if not all of them. With my pushing and prodding for them to remember such incidents, they may recall a couple of car accidents, and falls, and blows from sports, etc. But, the details remain murky, and I almost never get much in the way of specifics.

The inherent flaw of trying to figure out the number of TBI's a person has had as being "one, two, three, or too many to keep track of' is the same as classifying their severity. 'None' and 'too many' are *fairly easy* to identify. I hedge here because many people forget what has happened to them

over the years, especially as they become older. Others do not know, such as a baby accidentally being dropped by an older sibling, and the parents never being informed because the child is embarrassed. The middle two classifications (1 or 2 TBI's) are far murkier, such as trying to determine if a car accident at 25 MPH, classified as a fender bender by the person, did anything to permanently harm a person. Or, if a mortar blast from so many meters away caused a serious concussion that could lead to permanent damage.

Another way I have of trying to determine if a brain injury has occurred is to look at its effects. e.g. Adults will tell me that they were hit by a car as a pedestrian back in 1st grade. That sounds serious. But, I will follow-up and ask 'What kind of grades did you earn in school in subsequent years?' Often I have heard that they made straight-A's, or otherwise done very well. That is not absolute proof that the accident caused no TBI, but it is fairly good evidence.

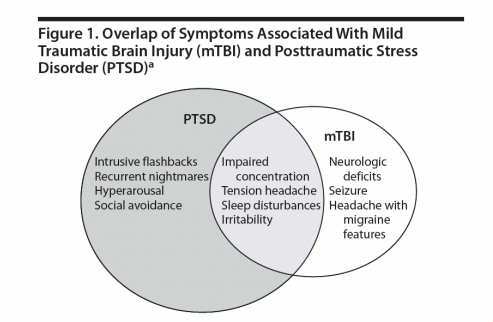
Veterans who have had blast exposure and/or falls who may have persistent post-concussion syndrome (PPCS) which is considered a mTBI, often complain of (in roughly decreasing order of frequency):

- sleep disturbances
- irritability
- attention/concentration difficulties
- mood swings
- memory problems
- anxiety
- headaches
- light/noise sensitivity
- depression
- visual disturbances
- tinnitus (ringing in the ears)
- excessive fatigue
- balance problems
- dizziness

There is no formal definition of PPCS that everyone agrees on. However, having at least three of these symptoms persist for a period of time, perhaps three months or more, is accepted by many as being reasonable.

Some suggest that such symptoms should arise within the first week after an incident. But I frequently hear that people were unaware for various reasons (e.g. they were still busy fighting in a war zone, or working to support themselves and their family) to slow down and take notice of such problems and so I do not use 'it has to appear within a week' as a criteria.

When I see such a long list of problems in someone it makes me more suspicious that PPCS may be present. But, the problem with such a list of complaints is that they can arise for reasons other than PPCS. For instance, tinnitus is something I hear about in close to 100% of the veterans I work with – simply because of common exposure to loud noises on a daily basis, be it rifle fire on the range, being around noisy engines such as wheeled and tracked vehicles or aircraft, etc. And tinnitus can impact people in various ways including the ability to focus, or contribute to depression, anxiety, anger, or impair sleep. Plus, vets who have been exposed to concussive blasts are quite likely to have experienced traumatizing moments in combat that can lead to PTSD. And PTSD's effects can include problems with sleep, anxiety, irritability, depression, and fatigue. So, maybe such symptoms being present are from PPCS, or tinnitus. Or from PTSD. Or something else all together such as being depressed and anxious about transitioning to civilian life.



Taken from Journal of Clinical Psychiatry, "Military- and Sports-related mild traumatic brain injury: clinical presentation, management, and long-term consequences", 2013, Elaine Peskind et al

Risk factors for PPCS can include:

- being female
- being older
- long headaches (some research suggests those lasting longer than 2 ½ days)
- prior history of concussion
- prior history of a longer recovery
- history of mood, anxiety, ADHD, or seizures
- history of migraines
- severe impact to the head
- there being a double impact to the head in the incident (e.g. hitting a windshield in an accident, and then flying through it and the head then hitting the road)
- the duration of the initial symptoms
- having multiple concussive symptoms

Another means to look for TBI/PPCS is if something has happened to their head, and the person has never again functioned well. In the more extreme cases, typically involving a moderate or severe TBI, the person will realize immediately, such as within a day or less, that their functioning has become impaired. They are suddenly depressed whereas they used to be happy. They are no longer able to work, and never return to employment again.

Recent research has looked at trying to predict when mTBI might lead to PPCS. The accuracy of doctors in the emergency room making such a prediction accurately is at chance levels. One study (Journal of Neurotrauma, "Post-concussion symptoms rule: derivation and validation of a clinical decision rule for early prediction of persistent symptoms after a mild TBI" Natalie LeSage et al, 9/29/22) found that several factors that can lead to fairly accurate predictions. They included

- being female
- prior history of TBI or mental health disorder
- headache while in the Emergency Room
- sleep disturbance

- fatigue
- sensitivity to light
- cervical sprain and hemorrhage on a CAT scan
- age (greatest risk was between the ages of 35-44, 45-54 was second greatest, 25-34 & 55-64 were roughly tied in 3rd place, and 14-24 or over age 65 were lowest).
- a score on the Rivermead Post-Concussion Questionnaire ≥21.

The researchers feel that being able to make a prediction of who may develop PPCS could be of benefit relative to

- who may profit from having extra interventions after they leave the ER
- who is not in need of extra attention/support after leaving the ER as to being less likely to develop PPCS
- and advancing the field as to research and clinical care to improve care and help prevent complications from such TBIs.

Milder TBI's typically see the person not realize the effects of the blow for weeks or months, and even years. Such individuals will return to work after a TBI such as from a car accident, but they are less capable of doing it than before. They get fired for the first time in their life. Or, they are more tired before the end of a day. They need assistance from others in ways they never did prior to the TBI. Veterans who have suffered a mTBI may return to the U.S. from deployment, and then try to go back to school, and find they are having problems with concentration such as for reading textbooks, or retaining what they learn in class. Or, they are far more irritable, and may be highly intolerant of others such as students in class.
Most people I have worked with professionally fall somewhere in the mild or moderate category of TBI's. Estimates are that about 75% of TBI's in the U.S. are mild in degree. But, remember my dislike for the professional definitions of 'mild'? So, take such numbers as being more murky than they may sound, and simply understand that milder TBI's out number more severe ones by a good amount.

The effects of TBI's

Many people with TBI's that I have seen over the years, including those with mild damage do not return to a fully normal function ever. What areas of functioning are most commonly affected?

Personality changes are very common, and they can take a serious toll on quality of life. The most common effects that I see, such as depression, irritability, or anger, may never fully disappear. Or, the person is not as capable in leading their daily life, such as having become scatter brained, disorganized, or forgetful. Many people pull back from social involvement. They find it is too hard to reach out to friends and relatives, and they no longer have the tolerance for dealing with crowds of people such as at a party or family gathering. Instead, they keep to themselves, do not make or return phone calls like they used to, and drastically reduce social outings such as going to movies or eating out.

Spouses – usually wives – often tell me they have another child to raise now. That is, there are so many emotional and behavioral problems resulting from the brain injury, that the person has become child-like, such as being very dependent and no longer fully capable of functioning in an adult manner. Divorce rates are elevated in families where one spouse is brain injured.

Still other effects of personality change from brain injury include the person being more disinhibited. Personality regulation can be thought of as involving a 'gas pedal' and 'brake.' That is, there is a time to be energetic and excited, and a time to be quiet and very controlled. There is a balance between the excitatory and inhibitory, and where that balance is shifts with the moment and situation. Being a 'stick in the mud' at a New Year's eve party is not good. Being rambunctious, boisterous or talking loudly while sitting in a religious sanctuary attending services on the Sabbath is equally inappropriate. What is important to understand is that the capacity to regulate and moderate such emotional display is frequently lost when TBI's occur.

When a person is brain injured and disinhibited they are like what I call 'the little kid who screams in the grocery store.' The child wants something, such as candy seen in the check out line, and when the parent says 'no' the kid has an outburst. Other adults nearby will see and hear this, and realize it is just normal behavior in a child. Kids can get away with such fits, adults can not. If an older individual, including even a teen, who has suffered a TBI engages in such inappropriate displays of behavior, adverse consequences are highly likely. Students are suspended from school. Adults are fired. Police come and warn if not arrest offending individuals. There is also 2-3 times increased risk of suicide with impulsivity being one of the potential contributing factors for this occurring.

Why are there such societal intolerances from being disinhibited? With the more serious cases, what I see is too much irritability, anger, aggression or otherwise inability to get along with other people. Yelling, arguing, fighting, brandishing of weapons, or otherwise showing poor judgment (such as 'talking back' to a police officer who stops someone for a traffic violation) occurs. Or, getting in to road rage incidents, such as getting out of one's vehicle and physically assaulting the other driver can result, which may lead to legal charges being filed. Parents who are brain injured have little if any tolerance for their children's normal behavior (such as incessantly asking 'But why?' or sibling rivalry arguments). Employees question, challenge, or otherwise do not get along with their bosses. Verbal fights or silent dissension (disagreeing, but never having the energy or ability to resolve the argument and so it festers far too much) within marriages also is common. The cooperative nature and needed tolerance for each other that relationships require is lost.

One effect that I see very commonly but is often overlooked, or is largely unrecognized by society is that the brain injured person needs external controls imposed on them. In simpler terms, they end up in psychiatric hospitals and/or prison. e.g. It has been said that the most populated 'psychiatric facility' in the U.S. is the Los Angeles County jail. That too has been my experience: nearly 100% of prisoners that I have worked with in local jails and state prisons have suffered significant brain injury. Similarly, patients in psychiatric hospitals have a high rate of brain injury. One national estimate is that roughly 50% of psychiatric in-patients are brain injured. At some of the hospitals I have worked the number of brain injured patients in my experience has been close to 100%.

Why are so many psychiatric patients and inmates brain injured? They can no longer cope effectively. Or, they can not adequately regulate their behavior in ways that they need, or society requires. Depression becomes more severe. Impulsive acts such as assaults arise. Recklessness happens, such as repeatedly driving at very excessive speeds. Substance abuse with alcohol and/or drugs, perhaps in an attempt to self-medicate their anger/depression/irritability, becomes worse. Such substance abuse then leads to an increased rate of other types of unacceptable behavior. I should state that such individuals are typically not impacted by 'severe' brain injuries. Rather,

they most likely are in the 'mild' category as defined by other professionals as I mentioned earlier, but not necessarily by me.

Other common effects of brain injury involve cognitive skills. Short term memory in particular is quite fragile. Most everyone as they become older can make humorous quips about being forgetful and more absent minded. But the forgetfulness that stems from brain injury is worse, and can not be easily written off to normal aging.

Other cognitive effects of TBI often include decreased ability to pay attention and focus. The person's mind will wander, like those people who have attention deficit disorder. Complaints may include not being able to pay attention in meetings. They may sit silently while others are talking at the meeting and the information they later need for their job is not being absorbed. Or, they are making a presentation and not making sense, such as drifting or jumping around too much in their comments.

Executive skills are a critical component of cognitive functioning, and they are often hard hit by a TBI. These skills include the ability to:

- think and conceptualize an idea
- organize and plan
- initiate and persist at something as is needed
- be able to monitor for mistakes, and then catch and correct them in a timely manner
- being able to stop when appropriate
- moderate emotions as needed, such as balancing the 'brake' and 'gas' of personality as required in varying situations

The absence of executive skills can easily be seen by looking at little kids. Parents have to tell them every night 'Go brush your teeth… Now get in to your pajamas… Now bring me a bedtime book you want me to read…' Adults in contrast have to be able to do such skills on their own. They need to be able to juggle multiple balls in the air. Running their own life, being a spouse and parent, having a job and doing it effectively, all require effective executive functioning.

What happens when executive skills are lost? I already have mentioned disinhibition. Other forms of executive deficit from TBI's include insufficient organization and planning. Problems here may include not having the capacity to attend to the many details of daily life, at home, work or school. The brain injured drop the ball and forget to do something important. Or, they are unable to figure out the necessary steps of what to do and how to go about bringing it about. This may involve important facets of life such as the strategy to find a new job or place to live. The brain injured individual will talk about 'I have to get a job' or 'I need to find a new apartment' but never get around to doing the actual work because of too little organization and focus.

Still others may know what they have to do, and have an organizational strategy in hand – but never get around to actually 'getting in to gear' and doing it. Others may see them as being 'lazy' but in reality it is not from lack of desire that they are unable to initiate needed action. Rather, it stems from what is now missing in their brain's functional abilities.

Yet another problem that can arise with TBI's is someone who knows what to do, how to go about it, and begins the process that will get them where they need to go. But they still fail. These

individuals have lost the ability to look for, catch and correct mistakes in a timely manner. One analogy I use to describe such folks is that they are like the car driver who is making great time while driving fast on a highway – but they are going in the wrong direction and never realize it. Another analogy I frequently use is the football player who carries the ball down the field to score a touch down – but goes to the opposing team's goal post. Some will realize their mistake after the fact, and may be able to 'run the ball back up the field' again. Others catch their mistake too late, and are unable to get back on track. Or, they never catch the error at all.

Being able to stop doing something when appropriate is perhaps best appreciated by little kids who can engage in certain behaviors incessantly and upset their parents in the process.

- "But why?' questions asked ad nauseum.
- Constantly interrupting a parent who is talking on the phone.
- 'The screaming child in the grocery store' that keeps on having such a fit long past any comfortable point for the parent.

are all examples of not being able to turn off behavior when such cessation is needed. Again, kids can get away with such inappropriate behavior for the most part. Adults can not. Society, be it employers, spouses, family or friends are far more intolerant of such grossly inappropriate behavior. In the more extreme cases, psychiatric hospitalization or imprisonment can result.

There also has been some research on TBI and the development of PTSD. Research done at UCLA used rats that had been given concussions and others were not concussed. They gave electrical shocks to both groups of rats and flashed a light at the same time so they would learn 'flashing light means I'm about to be shocked.' Concussed rats learned faster to become fearful of the light, and they were slower in forgetting this link. Digging deeper into this it was discovered that the amygdala, which is the emotional center of the brain, had been left in a more excited state, readying it to learn fear. That is, having a TBI may make PTSD more likely. This has implications such as for military personnel put into combat situations where concussions result and the horrors of war are then more likely to create PTSD.

Sleep problems are another issue that can arise and have large impacts on the quality of a person's life. One study (cited in the Journal of Neurotrauma, July 2020) found that those with 'complicated mTBI' (such as having problems apparent on MRI or CAT scans of their brain) had more problems with fatigue and sleep/wake issues afterward, such as a third still having issues a year after the TBI. Such problems can include need for more sleep, poor sleep quality, excessive daytime sleepiness, and feeling fatigued.

Another study in the Journal of Neurotrauma ("Concussion and risk of chronic medical and behavioral health comorbidities" Saef Izzy et al, 2021) looked at 9,205 adult concussion patients and who were matched (by age, sex, and race) to 9,188 non-concussion controls. Most were 18-40 years old. Falls and motor vehicle accidents were the two most common causes of concussions, accounting for 48% of the cases. Findings included an increased rate of psychosis, being suicidal, and substance use in those who lost consciousness. Concussed patients were also found to be at risk for weight gain which might play a role in increased risk of cardiovascular problems. Most of the problems arose within five years of being concussed.

Recovery from & treatment of TBI's

The rule of thumb is that for adults who have suffered a TBI the vast majority of neurological recovery that will ever happen occurs in the first six months. Some professionals will say that neurological recovery continues out to twelve months, and some even suggest twenty-four months. I used to say that myself many years ago – but I have yet to see in my practice of the past forty-two years any significant recovery after six months. Various behavioral strategies – such as using smart phone apps for all manner of stuff like appointments and reminders - can be employed beyond the six month point of a TBI, and may be helpful to some extent.

Kids are different. It is often cited that kids' brains are more plastic meaning that they are more adaptive to traumatic insults, and they do better than adults who suffer such injuries relative to regaining lost skills. There is some truth to this assertion, but only partially.

How long they may recover on a neurological level is not as clear, and estimates are often put in the 3-5 year range after a TBI has occurred. How is 'kid' defined relative to age? That is another murky issue.

Individuals who are younger do better than those who are older in recovering from a TBI, all things being equal. How are these terms defined? Many will use the age of 40 years as the dividing line, although I also have seen age 30 as the cut point.

As to children, adolescents or teens doing better than those who are considered adult – there is good news/bad news. The good news is that kids in such age ranges do have more plastic brains. Their brains have not been hard wired as much as adults' brains. This might be likened to the well-publicized issue of stem cells that can be grown in to any type of cell in contrast to other cells, such as one for the heart or liver that is already formed and can never function in anything but that one role. I will not say that brain cells of kids have all the capacity of a stem cell, but they are *relatively* more flexible compared to an adult's.

The bad news is that kids' brains are still developing when they suffer a TBI. The brain for the typical person is not fully developed neurologically until roughly the age of 30 years on average. For adults who suffer a TBI, they generally have learned most if not all of the important foundation skills they need in life. e.g. They can dress themselves, multiply numbers, drive a car, follow a recipe. Language such as vocabulary, speech and writing are well developed. Motor skills like walking are fully formed. These abilities are burned in to the brain and are very hard to disrupt or destroy. It is possible to lose them, and probably every adult has heard stories of someone who was in a bad car accident, or had a stroke, and had to relearn how to walk or talk again, and that such efforts required months of time.

Kids, depending on their age when a TBI occurs, have learned little if any of such foundation skills. The TBI effectively throws a monkey wrench in to the learning process and makes it far more difficult to acquire such ability. That is, their knowledge is not burned in to their brains yet, and as such it is far easier to interfere with its acquisition and storage.

Ultimately, the issue of kids' brains being more plastic misses the point. Brain damage is never good to sustain. It never improves the quality of a person's life, or makes the individual more functional and skilled. It may make a person far more appreciative of life and good health, after

the fact, by way of realizing how much they unfortunately took for granted. But the price that has to be paid to acquire such appreciation can be extremely high.

The flip side of 'How fast does a person recover?' is 'How long do problems persist?' There is some new research that found systemic inflammation of the brain lasting for a year after a mTBI (cited in Journal of Neurotrauma, June 3, 2020). Symptoms of such inflammation might include brain fog, slowed thinking, fatigue, and depression. Inflammation also means brain cells are dying which causes it to atrophy and age faster than normal.

What can be done to treat TBI's? There are several approaches to consider. One is through diet as to foods that can reduce inflammation in the brain. Possibilities for doing so include: chia seeds, avocados, raw chocolate (cacao), green leafy veggies and broccoli including kale and spinach, coffee in moderation, and nuts especially hazelnuts and walnuts. Foods high in lutein and zeaxanthin (e.g. blueberries) may also be helpful.

Another approach to recovery from TBI is through physical exercise. There is strong research evidence through animal models that physical exercise helps, and some human research has found this too. Cardio exercise (aerobics) is known to be the best way to boost a brain chemical called BDNF (brain derived neurotrophic factor). BDNF grows new brain cells, strengthens the ones that already exist, and also help protect against cells being killed. Plus, it strengthens the connections between cells – and it is this connectivity that comprises memory and learning. And it is thought to reduce anxiety and depression which would help explain why mood improves with exercise.

BDNF is also being looked at for mTBI injuries along with PTSD, with both of these being the 'signature injuries' of military personnel who have served in the Iraq and/or Afghan wars. TBIs actually arise from two forms of damage. The first is the direct impact, such as striking one's head on an object, such as a vehicular window when a concussive blast from an IED blows a person's body around. Secondary injury to the brain arises from effects like inflammation, blood flow being lost temporarily (such as can happen if there is too much edema inside the skull, or from leaking blood), and toxic chemicals that are emitted by cells when they are dying). BDNF seems to play a major role in reducing secondary brain injury. Research also has found that BDNF is dysregulated in TBI and PTSD. Chronic stress – such as being in a combat environment – can reduce BDNF levels, and impair hippocampus functioning, as seen through animal research. It has therefore been postulated that BDNF can enhance cell connectivity and function in these conditions.

Rat research has found that daily exercise ramps up BDNF more rapidly than doing it on alternate days although after a month they were at the same level. When rats stopped exercising regardless if it had been daily or every other day, it took only two weeks for BDNF levels to drop back to the baseline. When the rats were allowed access to exercise again, BDNF levels increased back up in just two days. So, if you have been exercising regularly the hippocampus can regain the benefit of BDNF very quickly after a temporary break. The researcher concluded that daily exercise is best, but doing it every other day is still very good. It was also found that exercise in old rats made the brain function almost as good as young rats. Overall, exercise is considered to be the most surefire and fastest way to increase BDNF levels.

As to how much cardio should be done, research seems to point most often to 30, 45 or 60 minutes a day or every other day. There is also a question as to how intensely it should be done. One metric is to look at what percentage of one's maximum heart rate (cardio max, determined by

subtracting one's current age from 220) is being reached. Higher levels toward cardio max are generally at 80% or above. Moderate levels are more like 60-79% of cardio max. One study on young adult males from 2013 published in the Journal of Sports Science Medicine looked at twenty or forty minutes of cardio done at a moderate (60% level) or vigorous (80% level). In the subjects BDNF levels increased 32% vs. declined by 13% in the sedentary controls. Vigorous activity for forty minutes had the best benefit, and increased BDNF by 2.7 fold over the 20 minutes of vigorous activity. Forty minutes of moderate exercise was 1.4 times greater than the 20 minutes of moderate.

Another study from 2015 looked at twenty minutes of cardio at a 70% level, vs. twenty minutes of high intensity interval training (HIIT), with 1 minute at 90% and 1 minute of rest. The HIIT was more effective at increasing BDNF.

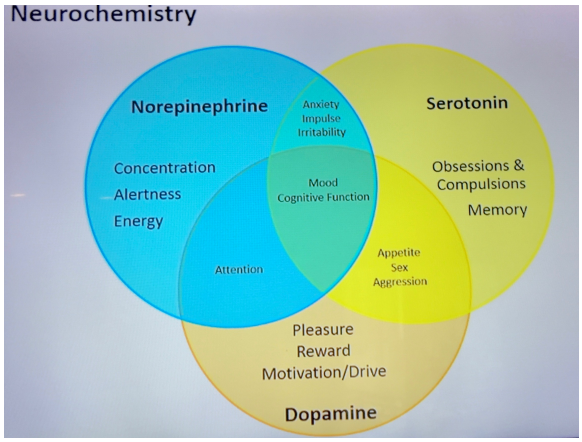
There is some emerging data to suggest that BDNF can start to impact the brain 5-6 weeks after aerobic training is started. There is also some research that persistent post-concussion syndrome may be related to abnormal cerebral blood flow, and that aerobic exercise can restore it to normal.

Resistance training (e.g. weights) may also be helpful in raising BDNF. One small study from 2017 was in the Journal of Science & Medicine in Sport. It looked at doing strength training (five sets of five reps, with 3 minute recovery) vs. hypertrophy (3 sets of 10 reps with one minute recovery). The latter was found to be more beneficial as to boosting BDNF. Another study looked at a year's worth of once or twice weekly resistance training in older women, and found it improved cognitive abilities such as attention and executive skills.

Richer social environments may also lead to increased BDNF and improved social behavior later in life, based on mouse research.
Exposure to the sun for perhaps 10-20 minutes increases BDNF, but taking supplemental vitamin D pills do not. Dietary approaches that may increase BDNF includes probiotics (yogurt, kefir, etc.), blueberries, cocoa flavonoids, and soy. There is some research by Dr. David Perlmutter that five strains of probiotics [1) L. plantarum, 2) L. acidophilus, 3) L. brevis, 4) bifiodobacterium lactis, and 5) B. longus] can increase BDNF. Intermittent fasting, such as going without eating for twelve or more hours, or caloric restriction may also boost BDNF. Omega 3's also can raise BDNF, and natural sources such as fish rather than supplements may be better. Meditation may be beneficial.

The standard American diet (aptly abbreviated as SAD) that is high in saturated fat and sugar is harmful to BDNF and brain function. There was some rat research done in 2012 where animals that had no bacteria in their gut had lower levels of BDNF. When probiotic bacteria were introduced into the guts of these rats their BDNF levels returned. Moral: we have to pay attention to what is going on in our guts and how it can impact our brains. f

Insomnia lowers BDNF levels. Acute, and even more so chronic stress decreases BDNF. Without enough BDNF there is decreased learning, and increased risk of Alzheimer's, epilepsy, anorexia, schizophrenia and OCD (obsessive-compulsive disorder). Levels also fall in women who are overweight. There is a genetic mutation that makes BDNF levels fall faster than average and this is present in one-third of people.



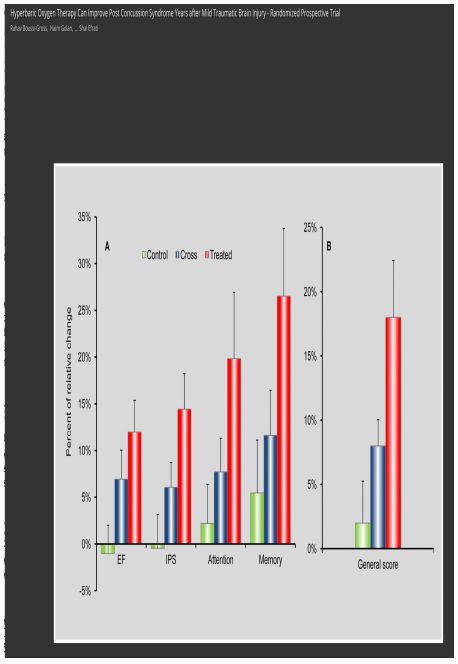
Three of the major neurotransmitters are norepinephrine, serotonin, and dopamine. All three of these are boosted by exercise. Look at the Venn diagram and see where all three of these chemicals intersect. Improving 'mood' is a broad concept. But factors that can take a toll on memory function include elevated levels of anxiety and/or depression. Look at some of the other benefits from boosting one or more of these neurotransmitters, and 'attention,' 'memory,' 'alertness,' 'concentration' are apparent.

YouTube: "Exercise is the best medicine for our brain" John Ratey, MD

One point to be cognizant of is that using exercise to recover from a TBI does **not** mean student athletes who have suffered a concussion, or others like military personnel, should be thrown back into intense physical activity right away. Taking some time off to let the brain heal before instituting an exercise program is advised.

Another technique that may be helpful with TBI is through hyperbaric oxygen treatment (HBOT), which is a scaled down version of decompression chambers that scuba divers use when they get 'the bends.'

Basically, brain cells can exist in one of three states: normal, dead and they are not coming back, and hanging on by a thread where they are nominally alive but no longer at a functional level. Some people refer to the third category as dormant and they can arise from problems like TBIs and strokes. HBOT can help such patients by repairing and creating new blood vessels in the injured areas of the brain.



"Hyperbaric oxygen therapy can improve post concussion syndrome years after mTBI – randomized prospective trial" PLOS 1, 11/15/2013, Rahav Boussi-Gross et al

EF=executive function. IPS=information processing speed.

An Israeli study on HBOT had 56 patients with prolonged post-concussion syndrome and found that many showed significant improvement in function and overall quality of life 1-5 years after a TBI leading to post-concussion syndrome, and SPECT brain imaging revealed elevated brain activity in good agreement with the cognitive changes.

Another Israeli study looked at 15 people with PPCS who received HBOT. Using brain imaging it was found that the patients had increased blood flow in the areas of the brain that had been previously dormant. Tests showed improved memory and processing speed. Yet another Israeli study done on 10 people who had suffered a TBI on average 10 years earlier used HBOT. Results included improved cerebral blood flow and –volume, along with significant improvement in information processing speed, visual-spatial processing, and motor skills.

2 short YouTube videos are at: https://youtu.be/wCwIZ4uutrs
and www.youtube.com/watch?v=ESeP8_eJyJ8&feature=youtu.be

Another Israeli study published Sept. 2018 in the British Medical Journal was the largest cohort study to date on HBOT, involving 154 patients. They had pre- and post-HBOT computerized cognitive testing and SPECT scans. TBIs had occurred anywhere from 3 months to 33 years earlier. HBOT was done for 40-70 daily sessions, with 60/90 minutes of 100% oxygen at 1.5/2.0 atmospheres. Patients ranged from mild to severe TBI.

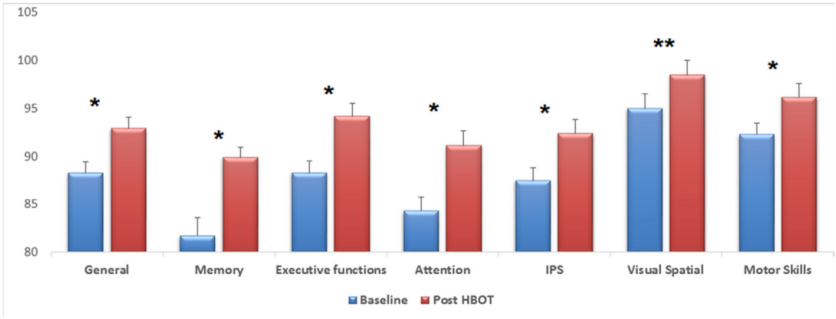


Figure 3 Mean changes of post-HBOT compared with pre-HBOT for the entire cohort. After HBOT, all cognitive domains improved significantly, with the most striking changes seen in memory and attention. *P<0.0001, **p=0.005, HBOT, hyperbaric oxygen therapy; IPS, information processing speed.

Hadanny A. *et al. BMJ Open* 2018;**8**:e023387. doi:10.1136/bmjopen-2018-023387

Above and below: "Effect of hyperbaric oxygen therapy on chronic neurocognitive deficits of post-traumatic brain injury patients: retrospective analysis" Amir Hadanny, et al, BMJ

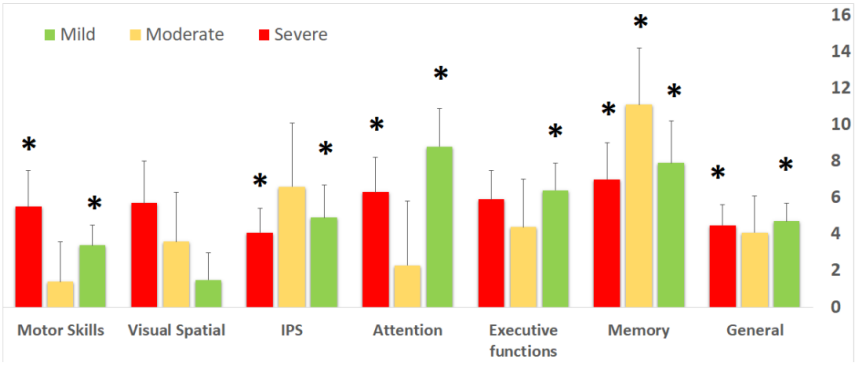


Figure 4 Mean changes of post-HBOT compared with pre-HBOT across the different TBI severities. Both patients who suffered mild and severe TBI groups had improvements in general, memory, attention, information processing speed and mot skills scores, whereas patients who suffered moderate TBI had significant improvement in memory. *P<0.05. HBOT, hyperbar oxygen therapy; IPS , information processing speed; TBI, traumatic brain injury.

Clinical improvements were well correlated with SPECT results as to increased brain activity in the relevant areas. It was suggested that beyond hyperbaric oxygenation, improvements might be due to improved mitochondrial function, cell metabolism, improved blood-brain barrier and inflammatory responses, reduced cell death, alleviation of oxidative stress, increased neurotrophins and nitric oxide. The common denominator of all these is they are oxygen dependent.

Paul Harch, MD who works out of LSU's School of Medicine came out with a study on HBOT in 2017 on 30 veterans aged 18-65, with mild-to-moderate TBIs at least a year old or persistent PPCS with or without PTSD. Compared to controls there was significant improvement in:

- PPCS symptoms
- PTSD symptoms
- neurological examination
- memory
- IQ
- attention
- cognition
- depression
- anxiety
- quality of life
- and brain blood flow

"Case control study: hyperbaric oxygen treatment of mild TBI persistent post-concussion syndrome & PTSD" Medical Gas Research, Sept. 2017, 7(3), 156-174, Paul Harch et al

Compared to the controls, the brains of patients receiving HBOT were "statistically indistinguishable in 75% of abnormal areas after treatment." There was also a significant reduction in suicidal ideation and anxiety. Harch concluded, ***"The PTSD symptom reduction is one of the greatest reductions in PTSD symptoms in a four-week period with any reported treatment, and combined with the effect on PPCS outcomes, HBOT represents the only reported effective treatment for the combined diagnoses of blast-induced persistent PPCS and PTSD."***

Still other improvements found in this study included stopping or reducing psych meds even six months after the treatment had ended. He also cites that all positive outcomes for PPCS were at pressures below 2 atmospheres.

Table 3: Symptoms of mild traumatic brain injury persistent post-concussion syndrome with or without post-traumatic stress disorder before, immediately, and 6 months after treatment

Ranking of subjects' symptoms (Ss)	Before HBOT (% of Ss Reporting)	After HBOT (% of Ss "Better")	6-month follow-up (% of Ss "Better")
Thinking/cognition	100	90	96
Low energy	100	86	93
Headache	97	93	86
Depression	90	92	87
Mood swings	86	84	96
Short-term memory loss	83	83	91
Sleep disruption	76	73	80
Short temper	72	90	95
Imbalance	69	65	88
Decreased hearing	69	10	22
Speech problems	62	78	87
Tinnitus	58	47	56
Photophobia	55	50	64
Paresthesias	48	57	60
Decreased vision	48	64	71
Arthralgias	45	54	22
PTSD symptoms	34	60	75
Dizziness	34	100	100

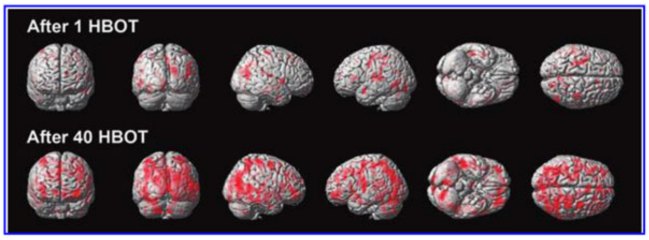
Note: HBOT: Hyperbaric oxygen therapy; PTSD: post traumatic stress disorder; "Better" means improved.

Another Harch study published in the Journal of Neurotrauma in 2012 looked at HBOT and PPCS from blasts suffered in the military along with PTSD. Fifteen active duty or recently retired service members were in the study who had diagnoses of TBI/PPCS with or without PTSD. The average age was 30, and were seen nearly three years after the TBI had developed. Some of the results included:

	% of participants who improved
Cognition	93
Short term memory	92
Headache	87
Energy level	87
Mood swings	87
Sleep disruption	75
Fine motor incoordination	75
Imbalance	55
PTSD	50
Photophobia	44
Tinnitus	37

IQ scores jumped by almost 15 points as to pre- and post-tests, and that is a large gain. For those taking psych meds or narcotics 64% either reduced or got off the drugs. In a follow-up after six months 92% were still improved by patient report.

HYPERBARIC OXYGEN AND CHRONIC TRAUMATIC BRAIN INJURY



Brain scans done in this study, with significant increases shown in red, as to the effect of 1 and 40 HBOT treatments.

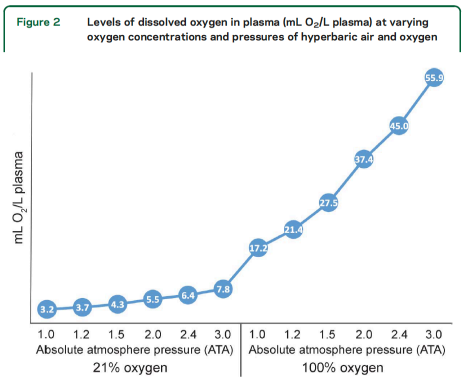
A 10 minute video by Harch is at: https://www.youtube.com/watch?v=wCwIZ4uutrs&feature=youtu.be

A 15 minute video by a West Point grad on TBI & HBOT is at: https://youtu.be/zlTpAJPuYT8
A 9 minute video of a vet with a 22 year old TBI, before and after HBOT: https://www.youtube.com/watch?v=uMHSptPjLXc

A meta-analysis on HBOT ("Hyperbaric oxygen therapy for the treatment of traumatic brain injury: a meta-analysis" Neurological Sciences, 1/8/2016, Fei Wang et al) looked at eight studies with the average age of patients 23-41 years old. HBOT treatment led to a higher score (which is better) on the Glasgow Coma Scale, "in addition to greater improvement in Glasgow Outcome Score and lower mortality, as compared to the control group… suggesting its utility as a standard intensive care regimen in traumatic brain injury."

The VA has not found HBOT effective for PPCS/TBI issues or at best they are straddling the fence on it (https://www.hsrd.research.va.gov/publications/esp/hbot.pdf). The Israeli researchers and others have publicly criticized the poor design of the VA research protocols along with results' interpretation and said that could be why they found it did not help. As of 2017 the VA started saying at least some of the time, 'Yes, HBOT can be used on vets even though we don't believe in it.' NC is one of the states that nominally is allowing HBOT to be used on PTSD and/or TBI vets, but Tricare, Medicare, Medicaid and other insurers don't cover the cost. As of 2019 no VA in NC had a HBOT facility in-house.

Other research ("Hyperbaric oxygen: B-level evidence in mild traumatic brain injury clinical trials" American Academy of Neurology, 2016, Xavier Figueroa & James Wright) offered

> "Hyperbaric oxygen and hyperbaric air have demonstrated therapeutic effects on mTBI/PPCS symptoms and can alleviate posttraumatic stress disorder symptoms secondary to a brain injury in 5 out of 5 peer-reviewed clinical trials. Four pivotal US-based trials [including Harch, 2012] and one Israeli-based clinical trial [Boussi-Gross, 2013] have provided well-structured and controlled studies that demonstrate reparative effects in mTBI/PPCS symptoms with HBOT.
>
> The apparent dose response profile strongly suggests that lower pressures (≤2.0 atmospheres) and lower oxygen levels (<100% O2) are potentially better for mTBI/PPCS and PTSD symptom recovery. Like prescription drugs, there is a Goldilocks zone when using HBOT (or hyperbaric air [HBA]) for treating mTBI/PPCS: too much may impair repair mechanisms; to little may not provide sufficient support; just right ensures that repair mechanisms are optimized.
>
> 
>
>
> The notion that low-pressure pure oxygen or high-pressure air can be a sham [for a control group, such as suggested by the VA] is not supported by the cell culture and animal data [and as shown in Figure 2].
>
> It would be a great loss to clinical medicine to ignore the large body of evidence collected so far that consistently concludes that HBOT is effective in treating brain injuries.
>
> The reported positive outcomes and durability of those outcomes has been demonstrated at 6 months post-HBOT treatment. Given the current policy by Tricare and the VA to allow physicians to prescribe drugs or therapies in an off-label manner for mTBI/PPCS, it is past time that HBOT be given the same opportunity."

The major side effect that is of most concern from HBOT is seizures can result. One study on moderate to severe TBI found that 2 atmospheres of pressure had a 9% seizure rate. With pressures below that side effects "have been noted only with prolonged courses of HBOT, i.e. 70-500 treatments" (as cited in Harch 2017). Minor side effects can include issues like pressure on the ear drum, or impacts on the sinus that can be reversed by stopping treatment.

A third approach that holds promise in my opinion is called neurofeedback or EEG biofeedback. It involves placing electrodes on the scalp and reading the brain waves, and giving auditory and/or visual feedback which 'trains the brain' to heal itself. The procedure entails very little of the patient, beyond sitting, relaxing and paying some attention to the feedback. Research on neurofeedback and TBIs is still in the earlier stages, but a number of studies have been promising. It has included improvements in various TBI deficits. It also has resulted in what has been called an increase in quality of life such as feeling happier, and having less guilt or feelings of being a failure arising over deficits that impair daily functioning such as difficulty with school, work, or

parenting that have arisen since the TBI. Some research has found as many as 88% of TBI patients making "significant improvement" through neurofeedback. But, such research is still in the earlier stages, and no guarantees about its effectiveness are being offered.

The most striking piece of research in my opinion about neurofeedback being helpful in brain injuries is that it was done on thirty-two patients who had been in a deep coma for two or more months. Twenty-five of them came out of the coma after just 1-2 sessions of neurofeedback, and two others needed some additional sessions to come out of the coma; five did not respond.

Some research that came out of UC San Diego in 2018, published in Brain Injury used micro-current neurofeedback on concussions. There was a 53% reduction in PPCS symptoms after only 12 sessions, with improvement in "headaches, insomnia, anxiety, sensitivity to light & sound, focus, concentration, memory, tobacco use cessation, stuttering, and feelings of frustration." https://microcurrentneurofeedback.com/concussion-sufferers-clinical-study/ (Micro current neurofeedback involves 3 trillionths of a watt stimulation to the nervous system "resulting in a temporary fluctuation in brainwaves. This change allows the brain to reorganize itself. This is analogous to re-booting a computer." (https://microcurrentneurofeedback.com/micro-current-neurofeedback/)

A fourth possibility is to go to a facility that specializes in brain injury rehab. This is best done fairly early on after a brain injury has occurred. Such treatment programs are like any other educational approach: one is taught various skills, and they then need to be practiced on a regular basis.

I have never seen anyone recover much through a rehab program. Some say they have made partial recovery of their impaired functions. The patients inevitably realize that some functions remain weak, as do their families, friends or employers. i.e. Rehab might help somewhat, but it leaves a lot unimproved. It should also be appreciated that if the TBI is not recognized that quickly, or if it is but it is not treated soon enough, the six month window of opportunity to effect brain healing is closed. Veterans who have been injured in the recent wars are often an example of this problem. They are hit by a concussive blast such as from an IED, might get a day or a week with light duty or 'sick in quarters' back on base, and then are sent back in to combat, and it may not be for months or years before they have the time and opportunity to go to a TBI clinic and seek help for issues that have arisen.

A fifth approach is to use psychiatric medication symptomatically. One of the more common problems after a TBI is poor attention and focus, which is fairly similar to attention deficit disorder (ADHD) in its appearance. There are any number of drugs that might help a person be more attentive.

Other TBI patients struggle with depression, such as being more socially withdrawn, isolated, or otherwise unable to handle the demands of being with most people in their lives. Antidepressant medication is often prescribed to them.

A third set of TBI patients have major problems with poor frustration tolerance, increased irritability or aggression, and are disinhibited. For such individuals mood stabilizing drugs are often recommended which is supposed to help even out such surges of emotion.

In my experience only a small percentage of TBI patients get any help through such medication. The vast majority complains of side effects being too severe, with the phrase of 'becoming a zombie' the most common one I hear. As a result, most TBI patients I have met may have tried various medications, but few are able to take them for any length of time.

Side effects are more intrusive to a TBI patient than someone who has not suffered such an injury. Consider what happens when a brand new, fresh off the showroom floor, car or truck tows some heavy trailer up a steep mountain road. It has the capacity to take such a load with relative ease. Everything is new and working well. Now take the same vehicle but after it has been driven 200,000 or 300,000 miles. How well will it tolerate the added strain of towing a heavy trailer? Every system, be it engine, transmission, suspension, etc. is aged and worn out. The odds are that any extra strain on the entire system will cause something to break. The same is true for people relative to medication side effects. The healthy brain can take the adverse consequences of drugs far better than the injured one, which has in effect undergone premature aging of its capabilities. This is not to say that medication should never be tried. It is worth considering. Discussing the issues with a medical doctor of one's choice, and further educating yourself as to what might be right for you is always a good idea. But, medication is like rehab: do not expect a miracle cure and a full return to one's previous abilities. And in my experience, do not expect very much if anything from meds.

Another approach that has received some research with military personnel, has been use of omega 3 fish oil. This is not a case where serious damage to the brain is done such as through explosive blasts, and taking a capsule or two of fish oil will magically heal everything fully and instantly. But, the type of fat in fish oil (DHA in particular) is a building block of the brain, and it may be helpful to some extent. Research (cited in the Journal of Alzheimer's Disease in 2017 done on psychiatric but not necessarily TBI patients) found that higher omega 3 levels correlated with higher blood flow in the brain as shown through SPECT scans. It was concluded that this may have implications as to contributing more to cognitive reserve.

There is also some early research on use of what are called near infrared (NIR) lasers. Red light in various wavelengths can penetrate through skin and even bone if it has enough power. It has been used to facilitate wound healing and muscle repair, treat problems like arthritis, back pain, heart attacks, skin ulcers, and reduce wrinkles such as in the face. Red light works on the mitochondria of cells and ATP production, meaning the energy that runs our bodies. More energy can be good such as if it is used for healing purposes, or fighting inflammation, etc.

One study took 10 TBI patients, veterans and civilians, who had suffered such an injury an average of about nine years earlier (but with a range of under one month to over twenty years prior). To get through the skull and penetrate deeper into the brain use of higher power lasers (10-15 watts) were used, and infrared light at 810 and 980 nm employed. The amount of energy delivered (measured at the scalp) was 55-81 joules/sq. cm. , and 10-20 sessions were completed. Some paper-and-pencil psychological tests were employed to measure issues like depression, and the patient and their spouse also maintained a diary of notes.

Problems they were dealing with included:

- over 90% had complaints of anxiety, depression, irritability, insomnia
- 60% had headaches
- 50% had suicidal ideation, attention problems, and cognitive difficulties

- 40% had short-term memory problems
- 30% had loss of libido
- 20% had substance abuse, fatigue, and panic attacks
- Six were unemployed
- Three were experiencing severe marital issues
- All carried a TBI diagnosis, but other diagnoses included PTSD, major depression, generalized anxiety disorder, bipolar disorder, and ADHD.

All ten showed significant improvement. "Insomnia and suicidal ideation, common symptoms in those with TBI or post-concussive syndromes resolved in 100% of cases. Headache, another common symptom for patients following a TBI, was reduced or resolved in the six patients so afflicted. Symptoms such as anxiety, depression, and irritability resolved or were dramatically reduced in all patients. Cognitive function appeared to improve based on return to work or improved work performance, although cognitive tests were not performed. The quality of life dramatically improved in all cases, based on the observations of the patients, their family members, and the treating clinician. At follow-up intervals of 6-7 months posttreatment, patients have reported continued improvements in symptoms." Symptoms consistent with PTSD also improved considerably or were resolved. (Neuropsychiatric Disease & Treatment, "Treatments for traumatic brain injury with emphasis on transcranial near-infrared laser phototherapy" Larry Morres, et al, 8/20/2015). This was a small study, it was not placebo controlled, or randomized, or well-researched such as through more advanced cognitive testing, brain imaging, etc. as to before vs. after. So it is best considered some early evidence of a possible approach to look into more over time.

The final approach to dealing with brain injuries is more personal. In simple terms, work harder and live healthier and you will do better. Families can also help toward such an end.

Work harder: it is very hard to succeed in any aspect of life if one never tries. We all can think of exceptions to such a rule, such as the person who never studies and makes A's in school anyway. But, the general principle remains true. Learning, or recovery from the impairments of TBI, takes effort. The more effort you put in the better you will do, all things being equal.

Live healthier: the absence of this is like the lung cancer or emphysema patient most of us have seen or heard about, who once diagnosed continue to smoke anyway. When are you going to learn? What is required to make you change self-destructive habits?

There have been any number of TBI patients I have seen over the years, often injured while they were driving drunk, that continue to drink alcohol. Some have even continued to engage in drunk driving. Others suffer brain damage from illegal drugs, such as cocaine or amphetamines, and have strokes or heart attacks which leads to brain damage. The message here is that when brain damage has occurred due to a serious breach of judgment, common sense, responsibility, or other factor – it is best not to compound one's problems and continue on the same path. Remember the geometric increase in risk of TBI measured against the number that has occurred? Or, how to count TBI's: 1, 2, 3, too many too keep track of. Don't make it worse by being self-destructive.

No one can prevent other drivers from rear ending them. Military personnel do not have much choice about getting blown up by IEDs, RPGs and the like. But when such major impacts to one's brain occurs, take stock of your choices in life and reassess what is going to be best for you going

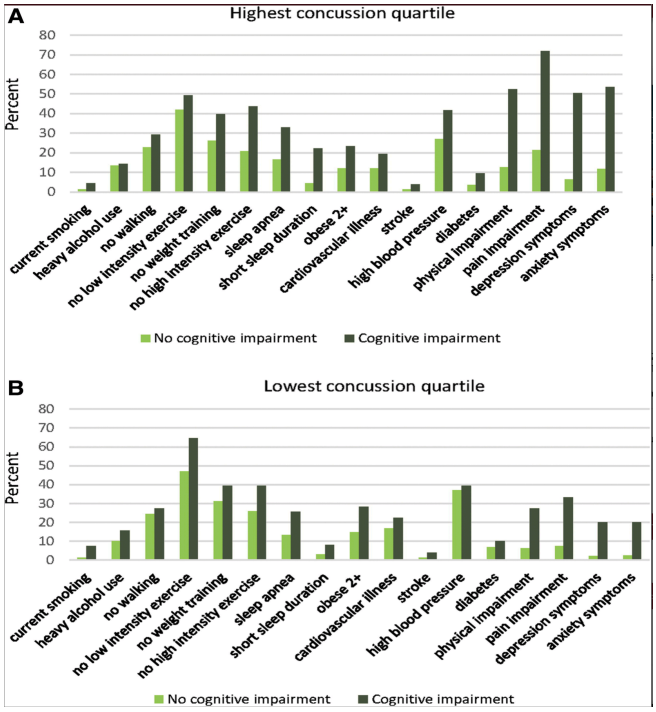
forward. Einstein's definition of insanity comes to mind: if you continue to do more of the same, you will continue to get more of the same. Make a choice to live healthier and get on a better path that will protect your brain's functioning as best as you can.

Family and friends can aide a TBI patient in various ways, which can make a significant difference in recovery. Emotional and financial support matter. 'Running interference' helps – such as taking on some of the burden of chores, like dealing with insurance companies, disability policies, employers' demands, etc. so that the patient spends more energy on recovery and less on the wearisome tasks of rules and bureaucracy.

The personal approach to dealing with TBI is not mutually exclusive to the others. They can all be used, or at least tried, in conjunction with each other. But, in my experience the people who do the best are the ones who try the most. Very little can be accomplished if a TBI patient gives up, does not care, or otherwise is indifferent toward recovery.

What about recovery from concussions and subconcussions? Subconcussions by definition have no overt symptoms. But that does not mean no damage is being done. Think again about bouncing your car over roads filled with moderate pot holes for years on end, and what that does as to developing rattles, and wearing out components too fast. Can you prove that those rattles developed because of the potholes? Probably not. But logically it makes sense and the odds are permanent damage is being done from repetitive subconcussive blows like heading a soccer ball thousands of times, or football linemen absorbing g-forces with *almost every* play.

Concussions are thought to be time limited, but the evidence coming in from the NFL football players of late has changed that. Research on the potentially permanent effects of concussions dates back at least to the early 1980s. So, consider concussions to be like TBIs, best to not have them. And if you do suffer one or more concussion, consider the treatments outlined above for TBIs. You should also look at the addendums on pages 24-27 of this article, which offers the opinions of some about how to handle concussions such as when to return to play in sports.



This graph is taken from the Harvard Football Players Health Study (2015-2019, involving 1900 participants, cited in Journal of Neurotrauma, Aug. 2020).

What it shows is that cognitive problems were generally higher among unhealthy individuals vs. healthier concussed. The largest differences were in high pain interfering with life, high depressive and high anxiety symptoms, and physical impairment. Sleep apnea, short sleep duration, no high-intensity exercise, no weight training, high blood pressure, and a BMI ≥35 also led to substantial differences.

What this means: these are largely modifiable risk factors. Improve them, and cognitive problems from a TBI may improve too.

Lessons to be learned

Given that the majority of civilian TBI's in the U.S. are preventable, in that they stem from accidents such as falls and motor vehicle accidents, the best approach to avoiding putting yourself or others you love at risk for a brain injury is to be more careful. Drive carefully and responsibly at all times. At a safe speed. Not under the influence of alcohol or drugs. Not when you are ready to fall asleep at the wheel. Not when you are seriously distracted such as texting. Being careful is needed around the house, such as on ladders, or on wet bathroom surfaces.

You should also learn and remember that technology has its limitations. Seat belts and air bags can only go so far in protecting a person. And their ability to prevent brain damage in a MVA is actually far less than most realize. Sports helmets also offer less protection against concussions than many believe. The problem is that the brain is basically sloshing around inside the skull, floating on cerebrospinal fluid. As such it will be hurled in to the interior walls of the skull when MVA's or sports impacts occur. Soft brain tissue thrown against hard bone is no match. That is, there is no seat belt or air bag *inside* the skull that will absorb the impact that occurs there. So, avoid such accidents or sources of blow to the head to the best of your ability.

Other lessons to be learned here is to be careful and act with forethought in other potentially hazardous situations. Falls around the house are a major cause of TBI's. This may include falls down stairs, out of windows or balconies, off ladders, out of trees, or from bikes ridden in the neighborhood. Think. Don't take unnecessary risks.

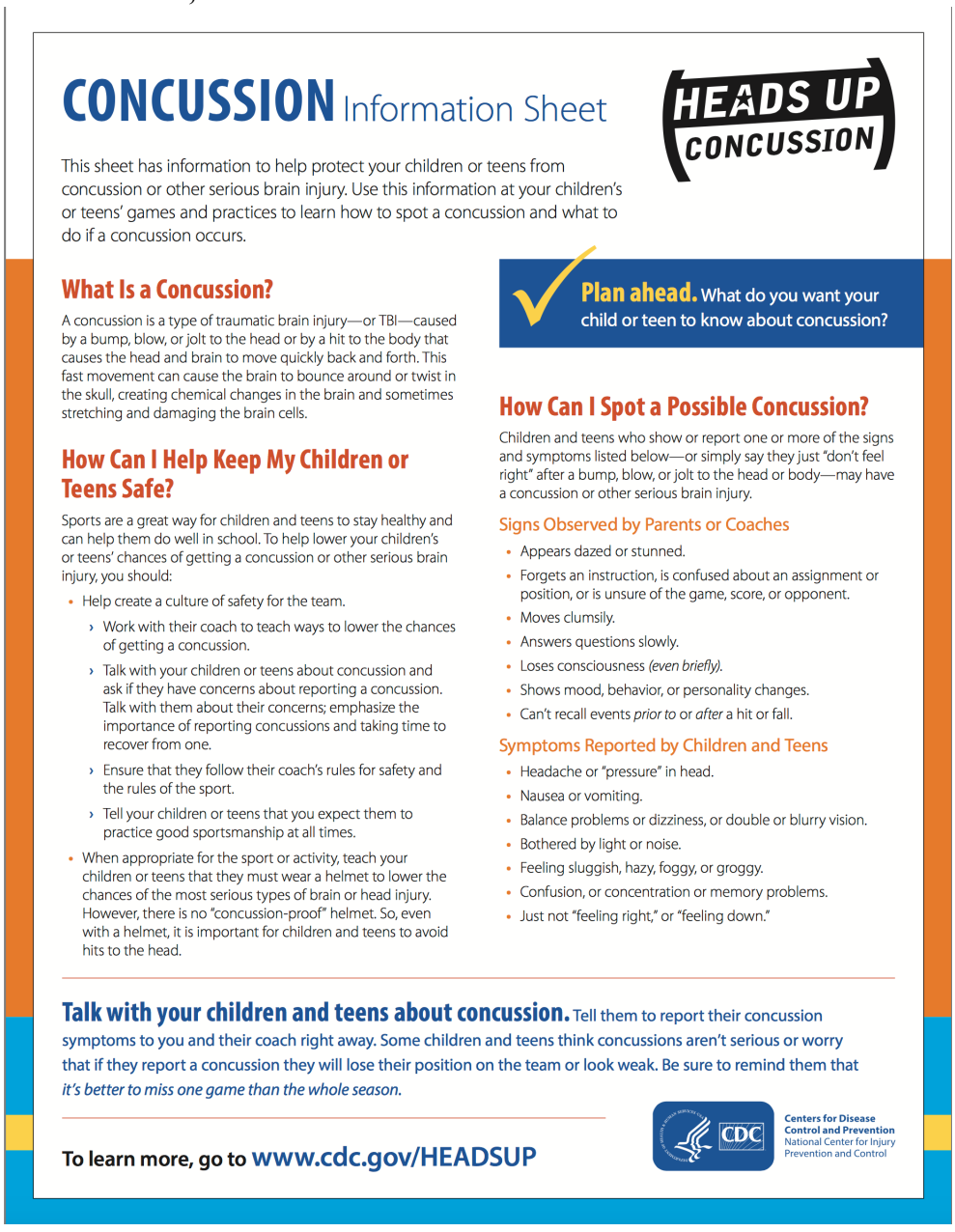
Sports are a hidden source of TBI's, as I mentioned at the outset of this article. I have seen many individuals over the years who probably suffered brain damage from sports, although virtually none were diagnosed before seeing me. That is, almost all such injuries go unrecognized. All types of sports are potentially dangerous. Baseball, football, soccer, hockey, basketball, lacrosse, riding a 10 speed bike at a modest speed while wearing a helmet, hang gliding… I've seen brain damage from all of these. Helmets may help a little, but they should be viewed as being more effective in

preventing something like cuts to the skin than a concussion to the brain. Realizing that 'it's only a game' may help even more and keep you or your loved ones safe.

The final thought to keep in mind is that virtually everyone I have seen who has suffered a brain injury regrets that single brief moment in time that it occurred. A blink of an eye. A fraction of a second. That's all it takes for a person's life to be permanently altered for the worse. There is no way to fully undo what happened, to erase the accident and injury.

So, be careful. Act prudently. Think. You only have one brain for your entire lifetime. Protect it and treasure its abilities, and you will live a far better life.

ADDENDUM, information from the CDC:



CONCUSSION Information Sheet

HEADS UP CONCUSSION

This sheet has information to help protect your children or teens from concussion or other serious brain injury. Use this information at your children's or teens' games and practices to learn how to spot a concussion and what to do if a concussion occurs.

What Is a Concussion?

A concussion is a type of traumatic brain injury—or TBI—caused by a bump, blow, or jolt to the head or by a hit to the body that causes the head and brain to move quickly back and forth. This fast movement can cause the brain to bounce around or twist in the skull, creating chemical changes in the brain and sometimes stretching and damaging the brain cells.

How Can I Help Keep My Children or Teens Safe?

Sports are a great way for children and teens to stay healthy and can help them do well in school. To help lower your children's or teens' chances of getting a concussion or other serious brain injury, you should:

- Help create a culture of safety for the team.
  - Work with their coach to teach ways to lower the chances of getting a concussion.
  - Talk with your children or teens about concussion and ask if they have concerns about reporting a concussion. Talk with them about their concerns; emphasize the importance of reporting concussions and taking time to recover from one.
  - Ensure that they follow their coach's rules for safety and the rules of the sport.
  - Tell your children or teens that you expect them to practice good sportsmanship at all times.
- When appropriate for the sport or activity, teach your children or teens that they must wear a helmet to lower the chances of the most serious types of brain or head injury. However, there is no "concussion-proof" helmet. So, even with a helmet, it is important for children and teens to avoid hits to the head.

Plan ahead. What do you want your child or teen to know about concussion?

How Can I Spot a Possible Concussion?

Children and teens who show or report one or more of the signs and symptoms listed below—or simply say they just "don't feel right" after a bump, blow, or jolt to the head or body—may have a concussion or other serious brain injury.

Signs Observed by Parents or Coaches

- Appears dazed or stunned.
- Forgets an instruction, is confused about an assignment or position, or is unsure of the game, score, or opponent.
- Moves clumsily.
- Answers questions slowly.
- Loses consciousness *(even briefly).*
- Shows mood, behavior, or personality changes.
- Can't recall events *prior to* or *after* a hit or fall.

Symptoms Reported by Children and Teens

- Headache or "pressure" in head.
- Nausea or vomiting.
- Balance problems or dizziness, or double or blurry vision.
- Bothered by light or noise.
- Feeling sluggish, hazy, foggy, or groggy.
- Confusion, or concentration or memory problems.
- Just not "feeling right," or "feeling down."

Talk with your children and teens about concussion. Tell them to report their concussion symptoms to you and their coach right away. Some children and teens think concussions aren't serious or worry that if they report a concussion they will lose their position on the team or look weak. Be sure to remind them that *it's better to miss one game than the whole season.*

To learn more, go to www.cdc.gov/HEADSUP

CDC Centers for Disease Control and Prevention National Center for Injury Prevention and Control

Concussions affect each child and teen differently. While most children and teens with a concussion feel better within a couple of weeks, some will have symptoms for months or longer. Talk with your children's or teens' health care provider if their concussion symptoms do not go away or if they get worse after they return to their regular activities.

HEADS UP CONCUSSION

What Are Some More Serious Danger Signs to Look Out For?

In rare cases, a dangerous collection of blood (hematoma) may form on the brain after a bump, blow, or jolt to the head or body and can squeeze the brain against the skull. Call 9-1-1 or take your child or teen to the emergency department right away if, after a bump, blow, or jolt to the head or body, he or she has one or more of these danger signs:

- One pupil larger than the other.
- Drowsiness or inability to wake up.
- A headache that gets worse and does not go away.
- Slurred speech, weakness, numbness, or decreased coordination.
- Repeated vomiting or nausea, convulsions or seizures (shaking or twitching).
- Unusual behavior, increased confusion, restlessness, or agitation.
- Loss of consciousness (passed out/knocked out). Even a brief loss of consciousness should be taken seriously.

Children and teens who continue to play while having concussion symptoms or who return to play too soon—while the brain is still healing—have a greater chance of getting another concussion. A repeat concussion that occurs while the brain is still healing from the first injury can be very serious and can affect a child or teen for a lifetime. It can even be fatal.

Revised 5/2015

What Should I Do If My Child or Teen Has a Possible Concussion?

As a parent, if you think your child or teen may have a concussion, you should:

1. Remove your child or teen from play.
2. Keep your child or teen out of play the day of the injury. Your child or teen should be seen by a health care provider and only return to play with permission from a health care provider who is experienced in evaluating for concussion.
3. Ask your child's or teen's health care provider for written instructions on helping your child or teen return to school. You can give the instructions to your child's or teen's school nurse and teacher(s) and return-to-play instructions to the coach and/or athletic trainer.

Do not try to judge the severity of the injury yourself. Only a health care provider should assess a child or teen for a possible concussion. Concussion signs and symptoms often show up soon after the injury. But you may not know how serious the concussion is at first, and some symptoms may not show up for hours or days.

The brain needs time to heal after a concussion. A child's or teen's return to school and sports should be a gradual process that is carefully managed and monitored by a health care provider.

To learn more, go to www.cdc.gov/HEADSUP

You can also download the CDC *HEADS UP* app to get concussion information at your fingertips. Just scan the QR code pictured at left with your smartphone.

Discuss the risks of concussion and other serious brain injury with your child or teen and have each person sign below.

Detach the section below and keep this information sheet to use at your children's or teens' games and practices to help protect them from concussion or other serious brain injury.

○ I learned about concussion and talked with my parent or coach about what to do if I have a concussion or other serious brain injury.

Athlete Name Printed: _____ Date: _____

Athlete Signature: _____

○ I have read this fact sheet for parents on concussion with my child or teen and talked about what to do if they have a concussion or other serious brain injury.

Parent or Legal Guardian Name Printed: _____ Date: _____

Parent or Legal Guardian Signature: _____

When should students return to play sports after a concussion is not well agreed upon. One set of guidelines from Brigham & Women's Hospital in Boston is very specific in recommendations. They offer five grades of concussions and return to play is based on the level of injury.

	Symptoms	Return to play…
Grade 1	mild physical trauma to the head such as a bump, contusion, or cut	as soon as the physical injury has healed
Grade 2	headaches that are often migraine-like, with associated symptoms	after they are asymptomatic, and undergo neurocognitive testing with results that are similar to their baseline
Grade 3	mTBI with a sudden change in mental status, or loss of consciousness (LOC) under 1 minute, or amnesia under 30 minutes	after at least 10 days before they participate in any activity that can result in head trauma. They must also be asymptomatic. After four such injuries return to play should only occur after receiving clearance from a neurologist or neurosurgeon.
Grade 4	TBI with LOC of 1-5 minutes, or amnesia between 5 minutes & 24 hours.	after a 30 day break for the first injury, 90 days for a second, 180 days after a third. They can then return to play if they are asymptomatic and neurocognitive testing is similar to baseline. Return to play after 3 grade 4 injuries is not advised.
Grade 5	may include physical injury to the brain, such as bleeding within it, increased intracranial pressure, LOC of more than 5 minutes, or amnesia of more than 24 hours.	maybe after 6 months if an MRI finds no evidence of structural damage inside the brain. They must be cleared by a neurologist or neurosurgeon. If the MRI shows damage then never returning to play is advised.

Other research has found that teens who continue to engage in full cognitive (academic) activity after a sports-related concussion took 2-5 times longer to recover (about 100 days vs. 20-50 days for those who limited cognitive exertion). Concussion experts and the American Academy of Pediatrics have come to recommend a period of near full cognitive rest for the first 3-5 days after an injury, and then a gradual return to academics as long as it does not trigger more concussion symptoms. Cognitive rest means:

- time off from school or work
- no homework
- no reading
- no visually stimulating activity (e.g. video games, computers, texting, use of cell phones, or limited or no tv)

- no exercise, athletics, chores that result in sweating
- no trips, social visits in or out of the home
- increased rest and sleep

Complete abstinence from cognitive activity may be unnecessary according to such experts.