Youth Sports and the Risk for Brain Injury: Balancing Risk and Benefit

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Disclosures

- Intellectual Property related to concussion and brain injury assessment
- Intellectual Property related to assessment of dementia after brain injury
- Intellectual Property related to treatment of intracranial hemorrhage

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- Abbott Diagnostic Laboratories
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- Hennepin Health Foundation
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- Islamic Medical Association of North America
- Minnesota High School Coaches Association
- National Football League
- National Neurotrauma Society
- North American Brain Injury Society
- Oculogica Inc
- Steven and Alexandra Cohen Foundation for Veteran Post Traumatic Stress and Traumatic Brain Injury
- Texas High School Coaches Association
- United States Veterans Administration and Office of Research and Development
- USA Football
Participation in Sports: Youth (ages 6-17)

- Athletic participation decreased 9.05%
  - In 2009: 50,287,000 participants
  - In 2014: 45,726,000 participants

Do sports cause death?

Riding in a car: 144 deaths per million

Equestrian: 20 deaths per million
Biking, snowboarding, skateboarding, skiing: all about 15 deaths per million
Football, playground activities: less than 10 deaths per million
Swimming: 140 pediatric deaths per year (confounded denominator)
What causes death from brain injury?

- In kids: accidents, homicide, suicide
- 11 American teens die every day texting and driving
- \( \frac{1}{2} \) of all brain trauma occurs in intoxicated people
Concussions in Sports Compared to Total Injury

Proportion of Total Injuries

[Bar chart showing proportions of concussions in different sports for high school and college.]
What are the long-term consequences of brain injury?

- Scalp Injury
- Skull Injury
- Compressive Lesions
  - Epidural / Subdural
- Subarachnoid Hemorrhage/IVH
- Diffuse Axonal Injury = CTE
- Anoxic Brain Injury = Permanent Neuro Deficit

Spinal Cord Injury = Paralysis

Inner Ear Injury - Dizziness

Endocrine Dysfunction = Depression, Suicidality

Cortical Spreading Depression = Headache, Seizures, Stroke

Prognosis

Best

Worst
>109,000 Swedes under age 25 with TBI compared to their siblings
Increased risk: pension disability, psychiatric hospitalization and premature death
Severity and number of injuries correlates with outcome
Suicide Risk Is Increased After Concussion
235000 pts followed for 9 years: 31/100,000

Risk of suicide after a concussion

Michael Fralick MD BScH, Deva Thiruchelvam MSc, Homer C. Tien MD MSc, Donald A. Redelmeier MD MS(HSR)


ABSTRACT

Background: Head injuries have been associated with subsequent suicide among military personnel, but outcomes after a concussion in the community are uncertain. We assessed the long-term risk of suicide after concussions occurring on weekends or weekdays in the community.

Methods: We performed a longitudinal cohort analysis of adults with diagnosis of a concussion in Ontario, Canada, from Apr. 1, 1992, to Mar. 31, 2012 (a 20-yr period), excluding severe cases that resulted in hospital admission. The primary outcome was the long-term risk of suicide after a weekend or weekday concussion.

Results: We identified 235 110 patients with a concussion. Their mean age was 41 years, 52% were men, and most (85%) lived in an urban location. A total of 667 subsequent suicides occurred over a median follow-up of 9.3 years, equivalent to 31 deaths per 100 000 patients annually or 3 times the population norm. Weekend concussions were associated with a one-third further increased risk of suicide compared with weekday concussions (relative risk 1.36, 95% confidence interval 1.14–1.64). The increased risk applied regardless of patients’ demographic characteristics, was independent of past psychiatric conditions, became accentuated with time and exceeded the risk among military personnel. Half of these patients had visited a physician in the last week of life.

Interpretation: Adults with a diagnosis of concussion had an increased long-term risk of suicide, particularly after concussions on weekends. Greater attention to the long-term care of patients after a concussion in the community might save lives because deaths from suicide can be prevented.
Suicide Mortality Among Retired National Football League Players Who Played 5 or More Seasons

Lehman et al 2016

3439 NFL players from 1959-1988 seasons were studied (minimum of 5 seasons per player) Followed for 28.9 years after retirement

Players retired - since 1987

6.1/100,000

Players retired - since 2005

12.5/100,000

Average American man - since 2014

20.1/100,000

Since 2005, NFL players are 48% less likely to commit suicide than the general population

Since 1987, NFL players are 70% less likely to commit suicide than gn’l population!

Drugs are assessed by standardized mortality ratio (the increase or decrease in mortality of a study cohort with respect to the general population).

If playing in the NFL (for a minimum of 5 seasons) was treated like taking a drug:

It reduces standardized mortality (measured 30 years later) by half!

Saving 296 lives at the cost of 17 deaths.
Suicide in the general population and NCAA athletes

Suicide in National Collegiate Athletic Association (NCAA) Athletes: A 9-Year Analysis of the NCAA Resolutions Database

Published Oct 2015

9 year study
3,773,309 participant seasons

General Population 12.6 per 100,000
18-22 year old non-college 12 per 100,000
College students 7.5 per 100,000
NCAA Athlete 0.93/100,000
NCAA Football (male only) 2.25/100,000
Decrease in Youth Athletics Compared to Youth Suicide Rate

NUMBER OF ATHLETIC PARTICIPANTS (AGE 6-17) COMPARED TO NUMBER OF SUICIDES IN TOTAL US POPULATION

Number of Suicides:
- 2009: 32,000
- 2010: 34,000
- 2011: 36,000
- 2012: 38,000
- 2013: 40,000
- 2014: 42,000

Number of Suicides: 100,000,000 - 32,000,000

A linear trend shows a decrease in the number of athletic participants compared to the number of suicides in the total US population.
An increase in sports participation (grades 7-12) leads to a decrease in depression by 25%

Suicidal ideation decreases by 12% with an increase in sports participation
What is the Relationship Between Concussion and Dementia?

- 1/3 of Americans have had a concussion in their lifetime, 2/3 of these are in males
- Dementia occurs about 63.5 per 1000 persons in the US
- Alzheimer’s twice as common in women vs men
- 5 Million have Alzheimer’s – no reliable diagnostic, unknown cause
- Other common types: vascular dementia, frontotemporal dementia, normal pressure hydrocephalus
What are the risk factors for dementia?

- High blood pressure
- Diabetes
- Sedentary lifestyle
- High fat diet
- Frequent alcohol use
- Female gender
- Low socioeconomic status (women)
- Smoking
- Atrial fibrillation
- Genetics
- Decreased level of education (women)
- Mild brain injury if over 65 years of age (men)
- Moderate or severe brain injury if over 55 (men)
4265 older adults followed for 45190 years

No association between a single brain injury and mild cognitive impairment, Alzheimers or other types of dementia
What is Chronic Traumatic Encephalopathy (CTE)

- First discovered in 1928 in NJ boxers published in JAMA
- Found in 17% of living professional boxers in England, named CTE in 1969
- Motor deficits, Dementia
- Pathology described in 1960’s and 1970’s at Queen’s Square, England
Omalu et al. and McKee et al. presented new definitions for CTE in the 2000s:

Chronic traumatic encephalopathy in a National Football League player.

Omalu BI, DeKosky ST, Minster RL, Kamboh MI, Hamilton RL, Wecht CH.

Chronic Traumatic Encephalopathy in Athletes: Progressive Tauopathy After Repetitive Head Injury

Ann C. McKee, MD, Robert C. Cantu, MD, Christopher J. Nowinski, AB, E. Tessa Hedley-Whyte, MD, Brandon E. Gavett, PhD, Andrew E. Budson, MD, Veronica E. Santini, MD, Hyo-Soon Lee, MD, Caroline A. Kubilus, and Robert A. Stern, PhD
“CTE, as defined in America, is not a neurological entity, but is a culture-specific social phenomenon.” Jim Andrikopoulos, British Medical Journal
Is Chronic Traumatic Encephalopathy a Real Disease?

Christopher Randolph, PhD

Abstract
Chronic traumatic encephalopathy (CTE) has received widespread media attention and is treated in the lay press as an established disease, characterized by suicidality and progressive dementia. The extant literature on CTE is reviewed here. There currently are no controlled epidemiological data to suggest that retired athletes are at increased risk for dementia or that they exhibit any type of unique neuropathology. There remain no established clinical or pathological criteria for diagnosing CTE. Despite claims that CTE occurs frequently in retired National Football League (NFL) players, recent studies of NFL retirees report that they have an all-cause mortality rate that is approximately half of the expected rate, and even lower suicide rates. In addition, recent clinical studies of samples of cognitively impaired NFL retirees have failed to identify any unique clinical syndrome. Until further controlled studies are completed, it appears to be premature to consider CTE a verifiable disease.

American football, or other sports involving repetitive head trauma. There have been only a couple of attempts to explore these risks via other methods. In 2005, Guskiewicz et al. (6) reported rates of mild cognitive impairment (MCI) and Alzheimer disease (AD) in retired National Football League (NFL) players that seemed to be higher than expected in comparison to population data. These results were based upon the responses to a survey sent to players who are members of the retired players association, and the results may have been subject to ascertainment bias. In addition, there were no controls.
Does a Unique Neuropsychiatric Profile Currently Exist for Chronic Traumatic Encephalopathy?


Abstract

There is evidence that repetitive mild traumatic brain injury leads to specific patterns of neuropathological findings, labeled chronic traumatic encephalopathy (CTE). However, questions remain about whether these neuropathological changes produce changes in behavior, cognition, and emotional status that are associated with a unique neuropsychiatric profile that can be assessed using currently available clinical tools. Our review of the literature indicates that insufficient evidence currently exists to suggest a distinct neuropsychiatric profile for CTE. Major limitations to the field presently include the relatively nascent nature of the topic, reliance on retrospective next-of-kin reporting, the lack of prospective studies, and similarities in neuropsychiatric symptoms between CTE, other neurodegenerative disorders and forms of psychopathology. Clinicians and researchers alike have a responsibility to adopt a cautious and balanced approach for antemortem assessments to minimize the potential unintended negative consequences of both overdiagnosing and underdiagnosing a clinical entity that has yet to be clearly established.
February 2015:
The feds step in to help define CTE: decide on 4 types but the first two are clinically asymptomatic.
the pathognomic lesion consists of p-tau aggregates in neurons, astrocytes and cell processes around small vessels in an irregular pattern at the depths of the cortical sulci
“a substantial number of neurologically unimpaired subjects even at a very old age display only sparse to modest extent of neurodegenerative pathology”
CTE is equally common in people with and without clinical neurodegenerative symptoms.

- CTE prevalence in people with neurodegenerative diseases (11.8%) was the same as in controls (12.8%).
- Patients with CTE died at a mean age of 81 years and that “most positive cases [were] likely to be clinically asymptomatic.”
- CTE is found under the microscope in equal proportions of healthy normal asymptomatic people as it is in people with dementia and other diseases.
Contact sport athletes, regardless of injury, are at increased risk for "symptomless" CTE

- CTE pathology in 21/66 former athletes; 3 had prior concussions.
- CTE not seen in 198 non-athletes, of whom 33 had documented head trauma.
- There was no association between clinical symptoms and CTE
- CTE is not the problem

- Deposition of tau may be a response to injury or opioids that is reparative or normal aging

71% NFL players have abused opioids
Concussion, dementia and CTE: are we getting it very wrong?

Alan Carson

A little less conversation, a little more science please

It is often said in the neuropsychiatry, but seldom considered in this particular literature, that one needs to think more of the nature of the brain which was injured than the nature of the brain injury.

In summary, the question concerned parents ask me is ‘what do I advise my own children?’ Tempting though it is, I do not duck the issue; however, I do always begin by cautioning that the evidence is incomplete for all potential harms, although reminding them it is more robust for benefits. I am delighted that my daughter plays
Does football increase risk of dementia?

438 Football Players followed for 50 years

Same risk for dementia as members of chorus, glee club or band

High School Football and Risk of Neurodegeneration: A Community-Based Study

Rodolfo Savica, MD, MSc; Joseph E. Parisi, MD; Lester E. Wold, MD; Keith A. Josephs, MD, MST, MSc; and J. Eric Ahlskog, PhD, MD

TABLE 1. Historical Cohort Study of Football Players vs Non–Football Players and Risk of Neurodegenerative Diseases

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Football players (N=438)</th>
<th>Band/glee club/choir members (N=140)</th>
<th>HR</th>
<th>95% CI</th>
<th>P value b</th>
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<tbody>
<tr>
<td>Follow-up</td>
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<tr>
<td>Years of follow-up a</td>
<td>50.2 (13.7, 57.5)</td>
<td>42.7 (8.8, 55.4)</td>
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<tr>
<td>Age at follow-up a</td>
<td>68.4 (31.5, 75.6)</td>
<td>59.1 (26.7, 73.4)</td>
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<td>.01</td>
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<tr>
<td>Outcome</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Dementia</td>
<td>13</td>
<td>2</td>
<td>1.58</td>
<td>0.36-7.01</td>
<td>.55</td>
</tr>
<tr>
<td>Parkinson disease</td>
<td>10</td>
<td>5</td>
<td>0.48</td>
<td>0.17-1.42</td>
<td>.19</td>
</tr>
<tr>
<td>Amyotrophic lateral sclerosis</td>
<td>2</td>
<td>1</td>
<td>0.52</td>
<td>0.05-5.68</td>
<td>.59</td>
</tr>
</tbody>
</table>

a HR = hazard ratio; CI = confidence interval.
b P values are for the Wilcoxon rank sum test.
c Values are median (25th percentile, 75th percentile).
Rochester Epidemiology Project

From 1956-70

296 varsity football vs 196 wrestling, swimming, and basketball athletes

Football players more likely to have had a concussion

No difference in likelihood of dementia, Parkinsonism or ALS >50 years after injury

High School Football and Late-Life Risk of Neurodegenerative Syndromes, 1956-1970

Pieter H.H. Janssen; Jay Mandrekar, PhD; Michelle M. Mielke, PhD; J. Eric Ahlskog, PhD, MD; Bradley F. Boeve, MD; Keith Josephs, MD; and Rodolfo Savica, MD, PhD

Abstract

Objective: To assess whether athletes who played American varsity high school football between 1956 and 1970 have an increased risk of neurodegenerative diseases later in life.

Patients and Methods: We identified all male varsity football players between 1956 and 1970 in the public high schools of Rochester, Minnesota, and non—football-playing male varsity swimmers, wrestlers, and basketball players. Using the medical records linkage system of the Rochester Epidemiology Project, we ascertained the incidence of late-life neurodegenerative diseases: dementia, parkinsonism, and amyotrophic lateral sclerosis. We also recorded medical record—documented head trauma during high school years.

Results: We identified 296 varsity football players and 190 athletes engaging in other sports. Football players had an increased risk of medically documented head trauma, especially if they played football for more than 1 year. Compared with nonfootball athletes, football players did not have an increased risk of neurodegenerative disease overall or of the individual conditions of dementia, parkinsonism, and amyotrophic lateral sclerosis.

Conclusion: In this community-based study, varsity high school football players from 1956 to 1970 did not have an increased risk of neurodegenerative diseases compared with athletes engaged in other varsity sports. This was from an era when there was a generally nihilistic view of concussion dangers, less protective equipment, and no prohibition of spearing (head-first tackling). However, the size and strength of the players was increased through weightlifting, and they were engaged in full-contact practices.
52 players; 29 controls
Averaged 22 years of professional international rugby play
14 concussions on average
Average age of 54 years at assessment

Controls: higher CV disease
No differences in cognitive testing, general or mental health
33 retired professional hockey players -- mean 5 concussions

18 controls – mean 0.6 concussions
So then why does this article about dementia feature a kid in a sports helmet?

**IMPERFECT SCIENCE**
1. no controls (normal children change as they develop)
2. ascertainment bias
3. outcome measures assess risk of brain injury but not risk/benefit of sports

**$$$$ MOTIVATIONS**
Researchers are dependent on positive results and “real life application” for their livelihood!

Lots of people want to profit from “the worried well” and kids playing sports
Researchers have found measurable brain changes in children after a single season of playing youth football, even without a concussion diagnosis, according to a new study published online, October 24, in the journal Radiology.
25 boys aged 8-13 studied with accelerometers

Change in FA plotted vs risk-weighted cumulative exposure

1. There are no controls in this study

2. One outlier creates “significance”

3. We have no idea what the kids were doing with their accelerometers (throwing them around)

4. We don’t know what the kids were doing outside of football
A normal child has changes in brain structure and function as they grow and develop.

Children learning to read activate different areas for speech as they progress...

What is ascertainment bias?

- Population Sample: 1000 People
- Ailment Incidence: 3%, 30 people
- High Exposure Individuals: 5%, 50 People
- Medium Exposure Individuals: 200 People
- Low Exposure Individuals: 450 People
- No Exposure Individuals: 300 People
Exposure to Contact Sports in General Population Sample

“Come to this clinic if you played football and feel sick”

- Only seeing high exposure cases that are suffering from the specified ailment.
- The result of this is a positive ascertainment bias for the increased exposure for contact sports.
93 former football players studied -- problems: ascertainment bias - no controls
45 former NFL players studied - Ascertainment bias can be used to demonstrate either side!
Age of first exposure to football and later-life cognitive impairment in former NFL players

ABSTRACT

Objective: To determine the relationship between exposure to repeated head impacts through tackle football prior to age 12, during a key period of brain development, and later-life executive function, memory, and estimated verbal IQ.

Methods: Forty-two former National Football League (NFL) players ages 40-69 from the Diagnosing and Evaluating Traumatic Encephalopathy using Clinical Tests (DETECT) study were matched by age and divided into 2 groups based on their age of first exposure (AFE) to tackle football: AFE <12 and AFE ≥12. Participants completed the Wisconsin Card Sort Test (WCST), Neuropsychological Assessment Battery List Learning test (NAB-LL), and Wide Range Achievement Test, 4th edition (WRAT-4) Reading subtest as part of a larger neuropsychological testing battery.

Results: Former NFL players in the AFE <12 group performed significantly worse than the AFE ≥12 group on all measures of the WCST, NAB-LL, and WRAT-4 Reading tests after controlling for total number of years of football played and age at the time of evaluation, indicating executive dysfunction, memory impairment, and lower estimated verbal IQ.

Conclusions: There is an association between participation in tackle football prior to age 12 and greater later-life cognitive impairment measured using objective neuropsychological tests. These findings suggest that incurring repeated head impacts during a critical neurodevelopmental period may increase the risk of later-life cognitive impairment. If replicated with larger samples and longitudinal designs, these findings may have implications for safety recommendations for youth sports. Neurology® 2015;84:1114-1120

Study of 42 former NFL players:

No controls
Ascertainment bias
Age at first exposure to tackling does not result in increased risk of neurocognitive deficits

American Journal of Sports Medicine
February 2016

Participation in Pre–High School Football and Neurological, Neuroradiological, and Neuropsychological Findings in Later Life

A Study of 45 Retired National Football League Players

Gary S. Solomon,† PhD, Andrew W. Kuhn,† BA, Scott L. Zuckerman,‡ MD, Ira R. Casson,§ MD, David C. Viano,‖ DrMed, PhD, Mark R. Lovell,¶ PhD, and Allen K. Sills,* MD

Investigation performed at Vanderbilt University School of Medicine, Nashville, Tennessee, USA

Background: A recent study found that an earlier age of first exposure (AFE) to tackle football was associated with long-term neurocognitive impairment in retired National Football League (NFL) players.

Purpose: To assess the association between years of exposure to pre–high school football (PreYOE) and neuroradiological, neurological, and neuropsychological outcome measures in a different sample of retired NFL players.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Forty-five former NFL players were included in this study. All participants prospectively completed extensive history taking, a neurological examination, brain magnetic resonance imaging, and a comprehensive battery of neuropsychological tests. To measure the associations between PreYOE and these outcome measures, multiple regression models were utilized while controlling for several covariates.

Results: After applying a Bonferroni correction for multiple comparisons, none of the neurological, neuroradiological, or neuropsychological outcome measures yielded a significant relationship with PreYOE. A second Bonferroni-corrected analysis of a subset of these athletes with self-reported learning disability yielded no significant relationships on paper-and-pencil neuropsychological tests but did result in a significant association between learning disability and computerized indices of visual motor speed and reaction time.

Conclusion: The current study failed to replicate the results of a prior study, which concluded that an earlier AFE to tackle football might result in long-term neurocognitive deficits. In 45 retired NFL athletes, there were no associations between PreYOE and neuroradiological, neurological, and neuropsychological outcome measures.

Keywords: concussion; football; National Football League; exposure; youth
The children who choose to play football have an average BMI of 26.3 and thus are at highest risk for complications of obesity. 

>1,000,000 American children play high school football (track 2\textsuperscript{nd}, b-ball 3\textsuperscript{rd})  
An additional >1,000,000 play Pop Warner or other league football  
\textbf{#1 participation sport in American high schools}  

If even half of those children became sedentary (rejected soccer, cross country and other fall sport options) the resultant increase in sedentary lifestyle/obesity risks would be enormous (hypertension, diabetes, cardiovascular disease, 13 cancers, osteoporosis)  

BMI of 17-25 is considered healthy
The obese child sees a greater cardiovascular risk reduction than the lean child with aerobic interval training.
The kids who are most likely to experience medical benefit from playing football are those who may not have predilection for other sports.
<table>
<thead>
<tr>
<th>Test</th>
<th>Units</th>
<th>Predicted</th>
<th>Pre Actual</th>
<th>Pre % Pred</th>
<th>Post Actual</th>
<th>Post % Pred</th>
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<td>FVC</td>
<td>L</td>
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<td>3.71</td>
<td>87 %</td>
<td>3.75</td>
<td>88 %</td>
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<tr>
<td>FEV1</td>
<td>L</td>
<td>3.64</td>
<td>2.57</td>
<td>71 %</td>
<td>2.55</td>
<td>70 %</td>
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<tr>
<td>FEV1/FVC</td>
<td>%</td>
<td>85 %</td>
<td>69 %</td>
<td>81 %</td>
<td>68 %</td>
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<td>5.63</td>
<td>80 %</td>
<td>5.98</td>
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<tr>
<td>Best FVC</td>
<td>L</td>
<td>4.27</td>
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<td>Best FEV1</td>
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<td>3.64</td>
<td>2.57</td>
<td>71 %</td>
<td>2.55</td>
<td>70 %</td>
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</table>
**BENEFIT**

None

- Reduces Obesity and Diabetes
- Reduces Depression/SI
- Reduces High Blood Pressure
- Reduces Heart Disease
- Reduces Stroke
- Reduces Dementia
- Reduces 13 Types of Cancer Risk
- Complex Psychosocial Benefit

**RISK**

High blood pressure
Vascular disease
Cancer
Lung disease
Seizures
Headaches
Motor Disorders
Depression
Executive Dysfunction
Cognitive Delay
Brain or Other Injury
Reduce Risk by Following American Academy of Pediatrics Recommendations

- Follow the rules
- Reduce contact drills/practices
- Neck strengthening
- Tackle technique improvement

WHEN AN INJURY OCCURS A KID SHOULD HAVE PROPER CARE
76% orthopedic chairs
86% neurosurgery chairs
90% TBI experts allowed their own children to play contact sports
suggesting that the more one understands brain injury the more likely they are to allow children to play contact sports

>70% pediatricians surveyed want to ban tackle football

Only 5.4% feel comfortable treating a child with PCS

<table>
<thead>
<tr>
<th>js2: Which sample group?</th>
<th>Orthopedic Surgery Chairs</th>
<th>Count</th>
<th>% within js2: Which sample group?</th>
<th>% within Does the subject have any child or children who have played contact sports?</th>
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<td>24.1%</td>
<td>75.9%</td>
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<td>46.7%</td>
<td>31.0%</td>
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<td>15.8%</td>
<td>84.2%</td>
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<td>40.0%</td>
<td>45.1%</td>
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<tr>
<th>Other TBI Experts (non-chair neurosurgeons, scientists, and chairs of other departments)</th>
<th>Count</th>
<th>% within js2: Which sample group?</th>
<th>% within Does the subject have any child or children who have played contact sports?</th>
<th>None</th>
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<th>Total</th>
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<td></td>
<td>2</td>
<td>17</td>
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<td>10.5%</td>
<td>89.5%</td>
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<td>13.3%</td>
<td>23.9%</td>
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<th>Total</th>
<th>Count</th>
<th>% within js2: Which sample group?</th>
<th>% within Does the subject have any child or children who have played contact sports?</th>
<th>None</th>
<th>Yes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>86</td>
<td></td>
<td></td>
<td>15</td>
<td>71</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Assessment of Possible Concussion

Tests that require baselines are not useful (especially in a developing child)! Any of: headache, nausea, vomiting, dizziness, vision problems, balance difficulties, forgetfulness, noise/light aversion, or other atypical behavior should prompt pulling the kid and seeking medical attention!!
Eye movements are conjugate in normals and disconjugate with brain injury (including concussion)
Best Resource for Concussion: cdc.gov/headsup/
Thank You!!