



# **Trying to Stay aHEAD of the Curve: The Implications of Repetitive Head Impacts in Sport on Long-Term Neurological Outcomes – Especially in the Sport of Soccer**

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# Disclosures

- No financial conflicts of interest.
- Research Funding from:
  - Under Armour



- NCAA/DOD Grand Alliance Care Consortium
- State of DE Economic Development Office
- AVEX/Footbeat Medical Advisory Board
- Tekscan, Inc.



- Have performed R&D work for Triax, Inc. but have received no financial compensation as a result.
- Isokinetic International website support.



# The Art of Football (Soccer) Heading from Two of the Greatest in the Game!





## Heading the Ball in Soccer Not a Significant Cause of Concussion

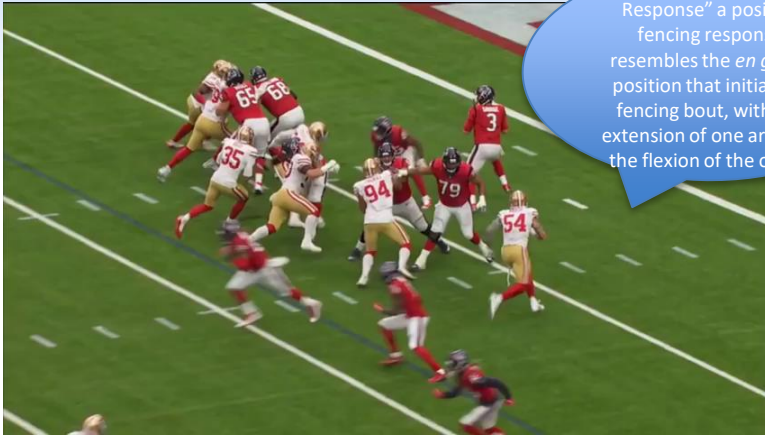
**A**lthough whether repeated, intentional headers can potentially cause brain injury later in life is unknown, existing data are encouraging in that there does not appear to be a correlation. A few early studies suggested that former professional soccer players may have cognitive impairment secondary to headers; however, in subsequent studies that controlled for complicating factors, such as alcoholism, drug use, and repeated more severe head injuries, this effect disappeared.<sup>13</sup> Biomechanical studies suggest that the force of a standing header is far below the theorized force necessary to cause a concussion.<sup>13</sup> In one study, most soccer-related concussions were caused by impact between 2 players; concussions caused by head-to-ball collisions occurred when an unprepared player was accidentally struck in the head with the ball.<sup>4</sup> It appears that the routine use of the head for controlling and advancing the ball—when performed properly—is not likely to be a significant factor in concussion and reported cognitive deficits.



# The Troublesome Hits in Futbol (Soccer)



# The Troublesome Hits in Football



Classic "Fencing Response" a positive fencing response resembles the *en garde* position that initiates a fencing bout, with the extension of one arm and the flexion of the other.

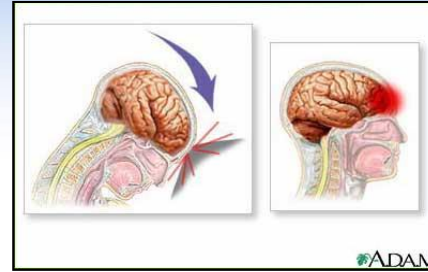


# Contemporary Definition of Sport-Related Concussion (SRC)

## • Concussion

Condensed from the 2012 definition that read "a physiological disruption of brain function caused by an external force and manifests as an alteration of attention and mental state and is indicated clinically by a new onset or worsening of a range of evolving signs and symptoms that are influenced by both intrinsic and extrinsic factors."

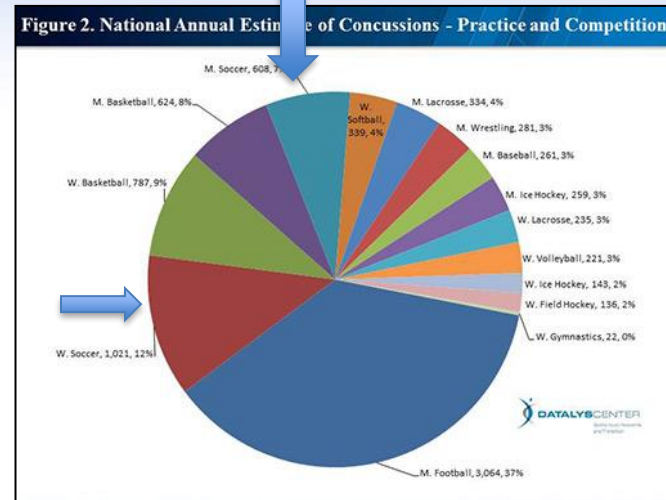
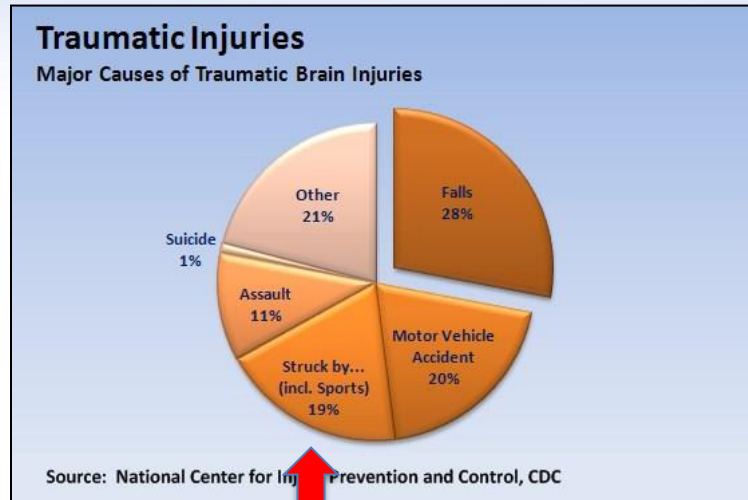
Concussion is caused by biomechanical forces.



Analogous  
to ice cubes  
in a glass of  
water!



# Sports-Related Concussion Incidence in the United States





# High School RIO™ Injury Statistics 2005-2006

SUMMARY REPORT

HIGH SCHOOL RIO™ (REPORTING INFORMATION ONLINE):  
INTERNET-BASED SURVEILLANCE OF INJURIES SUSTAINED BY  
US HIGH SCHOOL ATHLETES

2005-2006

Compiled by:  
R. Dawn Comstock, PhD  
Ellen E. Yard, MPH  
Christy L. Koos, MA  
Jennifer Manning, BA

**Table 4.6 Mechanism of Girls' Soccer Injury by Type of Injury**

	Sprain/Strain, n=108,556	Contusion, n=15,856	Fracture, n=14,068	Concussion, n=29,425	Other, n=25,766
Defending	12.3%	28.7%	21.5%	15.3%	14.9%
General play	16.6%	7.0%	10.9%	7.9%	17.9%
Ball handling/ dribbling	16.2%	16.6%	26.6%	6.1%	6.1%
Chasing loose ball	16.5%	9.6%	4.4%	11.9%	7.0%
Shooting/ passing	15.2%	7.4%	6.4%	0.7%	8.9%
Slide tackle	7.3%	0%	18.2%	5.1%	6.1%
Goaltending	3.3%	28.2%	8.5%	8.5%	0%
Heading ball	2.0%	2.5%	0%	37.2%	3.0%
Other	10.6%	0%	3.4%	7.2%	36.0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>



## Mechanisms of injury for concussions in collegiate soccer: an NCAA/DoD CARE consortium study

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### ABSTRACT

Over 9,000 concussions occur annually in intercollegiate soccer in the United States with little known about the incidence of mechanisms (e.g., collisions) and possible factors (e.g., sex) associated with each mechanism.

**Objective:** The purpose of this study was to describe the mechanism of injury (MOI) and examine factors associated with greater risk for specific MOIs involving concussions in collegiate soccer players.

**Methods:** Participants included 3,288 collegiate soccer players from 28 institutions across four competitive seasons, 2014–17. MOIs were documented for 262 soccer-related concussions during the study and placed into one of four categories: collisions, unintentional contact, aerial challenges, and others.

**Results:** 70% of the concussions occurred in DI soccer players. Collisions and unintentional contact were the MOIs that resulted in 66.5% of all concussions. DI and DIII soccer players sustained more concussions by unintentional contact versus collisions and aerial challenges when compared to their DII counterparts. Defenders were more likely than midfielders to sustain concussions by aerial challenges than collisions. As expected, the field players experienced more concussions as a result of collisions, unintentional contact, and aerial challenges when compared to goalkeepers.

**Conclusions:** Future research should explore preventive strategies for decreasing collisions, especially during aerial challenges while heading the soccer ball, and unintentional contacts from errant balls in soccer in order to decrease concussion risk.

### ARTICLE HISTORY

Accepted 6 October 2021

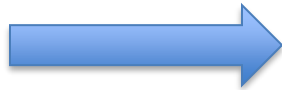
### KEYWORDS

Repetitive head impacts; football; aerial challenges; heading; concussion; mechanism

# The Pentagram of Concussion



A pentagram is the shape of a regular five-pointed star polygon, formed from the diagonal line segments of a convex regular pentagon. Drawing a circle around the 5 points creates a similar symbol referred to as the pentacle



## Abstract

**Background:** Multifarious clinical presentations of traumatic brain injury (TBI) makes detection difficult. Acceptance of the Fencing Response as an indicator of moderate TBI with localization to the brainstem expanded interest towards other possible indicators.

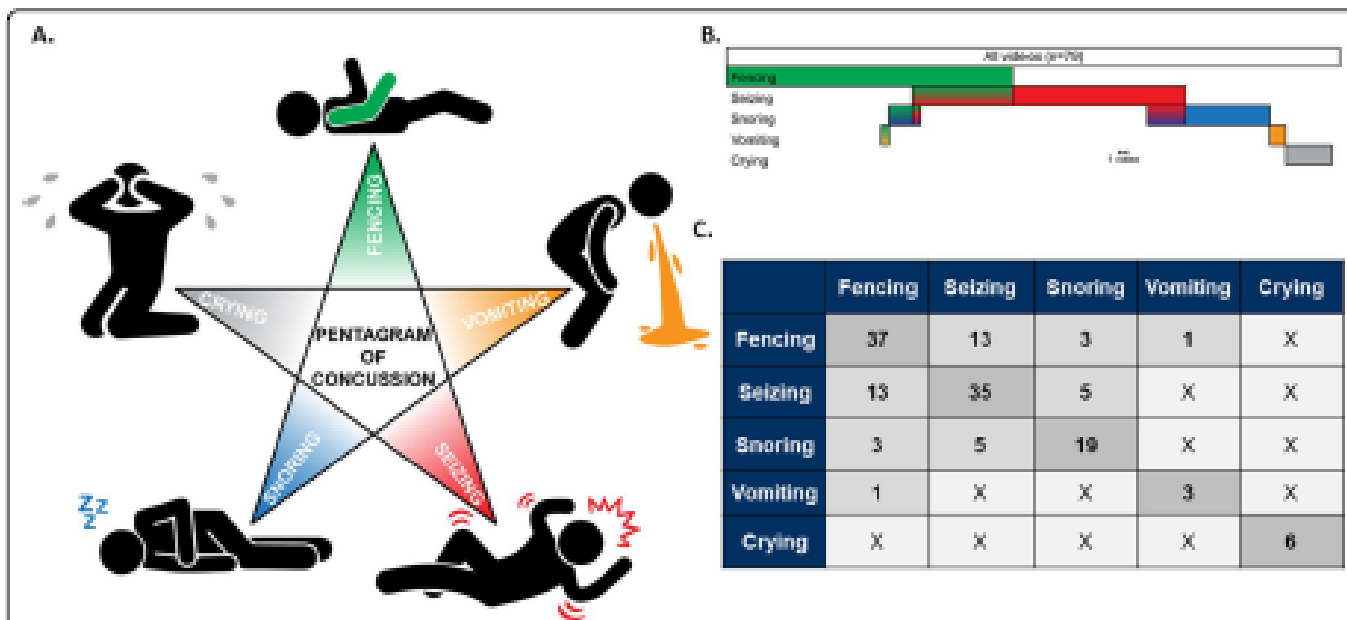
**Methods:** We hypothesized that an individual experiencing traumatic forces to the head resulting in concussion could display additional brainstem-mediated responses. Using YouTube™, videos were systematically evaluated for mechanical forces imposed on the head with a subsequent, observable behavior. Searches identified 9.9 million non-unique videos in which 0.01% were viewed and 79 met inclusion criteria. Videos of head injuries occurred during athletic activity (57%), assaults (38%), automobile accidents (4%) and impact by an inanimate object (1%).

**Results:** Individuals with acute head injury were identified as adults (70%; n = 55), teens (29%; n = 23), and children (1.2%; n = 1). Those identified as males made up majority of injured persons (n = 77♂, 2♀). Individuals in the videos were observed to demonstrate the Fencing Response (47%; n = 37), seizing (44%; n = 35), snoring (24%; n = 19), crying (7.6%; n = 6), and vomiting (3.8%; n = 3).

**Conclusion:** Each response, which together comprise the "Pentagram of Concussion", indicates the presence of traumatic forces to the head that present with one or more pentagram signs that would localize dysfunction to the brainstem. Clinical consideration of these responses helps to immediately identify patients at high risk for a brain injury with brainstem involvement that may have otherwise been mistaken for a different diagnosis.

**Keywords:** Brain injury, Fencing response, Concussive convulsion

# The Pentagram of Concussion



**Fig. 2** **A** Pentagram of Concussion depicting each pennant as the Fencing Response, seizures, snoring, vomiting, and crying. **B** Color bars indicate the distribution of each observable response identified immediately following head injury as a fraction of all videos. Bar length is proportional to the number of videos exhibiting each response. More than one color in a single bar indicate the occurrence of multiple responses following a single head injury. **C** Number of videos viewed with each observable response following head injury. Total videos identifying a specific response are shown with dark grey background



# Head Impact Kinematics

Comparison with  
everyday activities (1)  
head strike 11 g's, (2)  
chair plop 4 g's (3) head  
shake 4 g's, (4)  
“aggressive” pillow fight  
19 g's

Funk et al. 2010 Ann of Biomed Eng.

A force acting on a body as a result of acceleration or gravity, informally described in units of acceleration equal to one g. For example, a 12 pound object undergoing a g-force of 2g experiences 24 pounds of force.

If really interested  
here is an entire  
thesis devoted to  
everyday  
activities:

Linear and Angular Head Accelerations in Daily Life

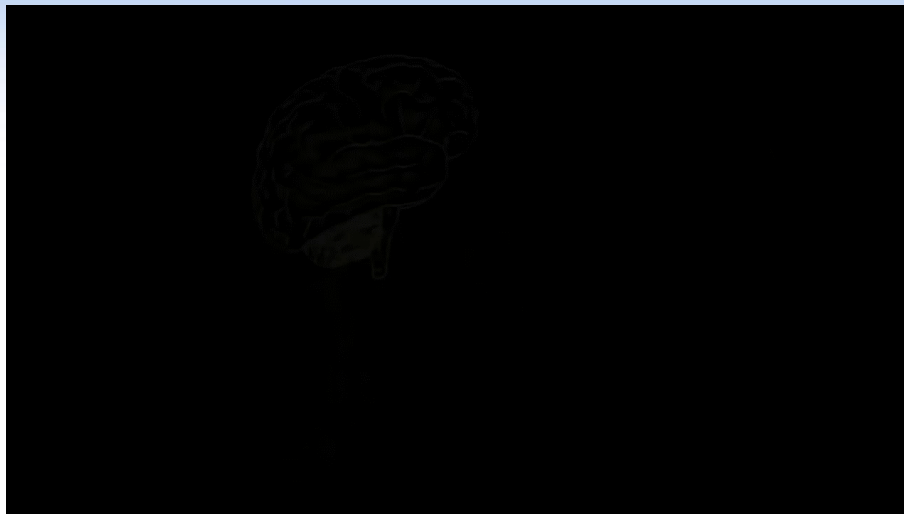
William R. Bussone

Thesis submitted to the Faculty of the  
Virginia Polytechnic Institute and State University  
in partial fulfillment of the requirements for the degree of

Master of Science  
in  
Mechanical Engineering

**Newton's Cradle = 39 g's**

# CDC's Concussion Video



# Another Way of Looking at Brain Motion during Concussion



- Shake an egg hard enough and the yolk will scramble despite the shell remaining intact!
- The jello-like brain floating in the skull, surrounded by shock-absorbing membranes called meninges, is *always* late to catch up!
- Linear forces ripple top to bottom – no big deal, take plate and twist the jello mold like a steering wheel --- quite a mess on your hands

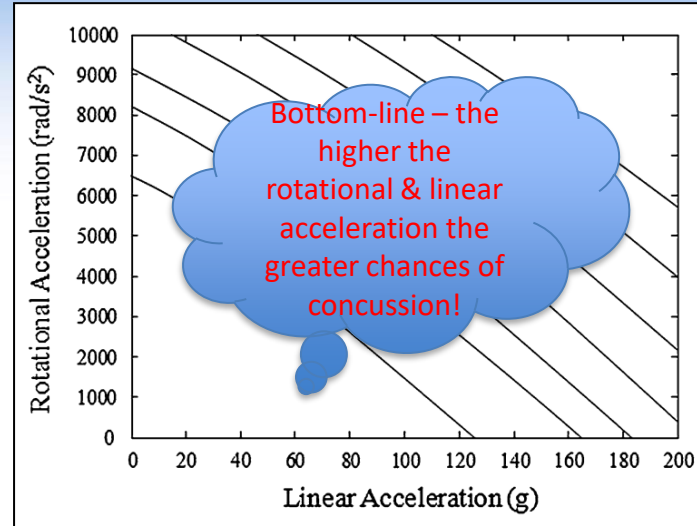
# A West Point Tradition Gone Awry!



The annual tradition, which dates back to at least 1897, has been a way for first-year cadets, known as "plebes," to swing a few pillows at their comrades and harmlessly blow off steam after a grueling, seven-week summer of training.

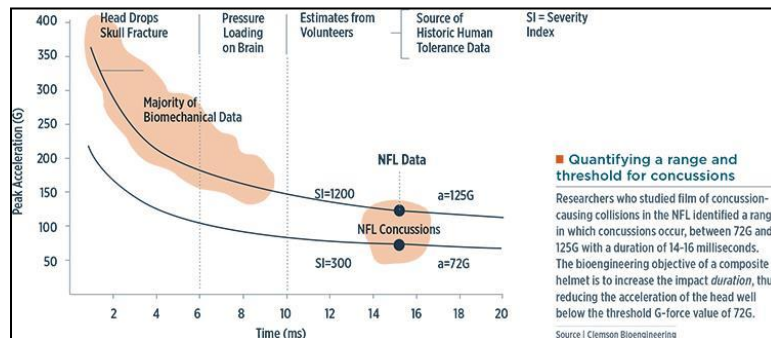
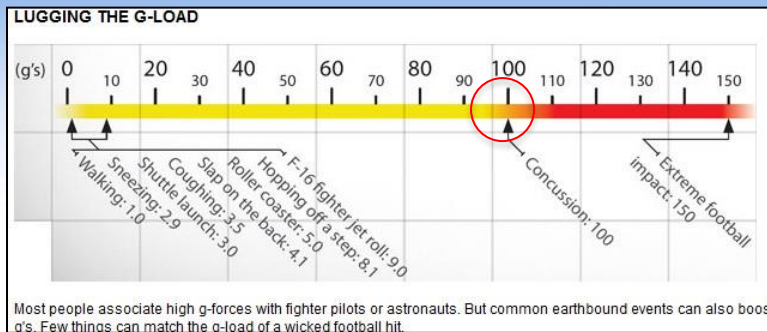


# Risk-Weighted Exposure and Cumulative Head Impacts



Combined probability of concussion contour given from the combined linear and rotational acceleration from Rowson *et al.* 2013

# Head Impact Kinematics



# Incidence of Concussion due to Heading a Soccer Ball

- A US Olympic Festival report indicated that 18% of the concussions resulted from heading –
- Two factors that have created the concern:
  - *Heading-Related Symptoms*
    - Headache
    - Neck pain
    - Dizziness
  - *Risk of Multiple (Successive) Concussions*
    - Each event reduces the “neuron reserve”, creating a deficiency that may become evident with future injury
- Others have raised the concern over damage to the cervical spine and TMJ regions



# Contemporary Evidence



ELSEVIER

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: [www.elsevier.com/ptsp](http://www.elsevier.com/ptsp)



## Why are female soccer players experiencing a concussion more often than their male counterparts? A scoping review

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School of Physiotherapy, University of Otago, 325 Great King Street, North Dunedin, Dunedin, 9016, New Zealand

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#### Article history:

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#### Keywords:

Concussion rate

Neck strength

Head acceleration

Female

### ABSTRACT

**Background:** The risk of concussion is particularly high in female soccer players. There is no consensus as to why female soccer players are at an elevated risk.

**Objective:** To synthesise current evidence investigating reasons for the increased concussion rate in female soccer players.

**Sources:** Searching of six databases (MEDLINE, Scopus, CINAHL, SportDiscus, Web of Science and the Cochrane Library) and grey literature was performed between 13/07/2020–31/07/2020. Keywords were concussion-related terms, terms relating to female football/soccer and terms relating to the mechanism/cause. No constraints were placed on publication date and quantitative or exploratory studies meeting inclusion criteria were eligible. Exclusion criteria were studies not published in English and qualitative studies.

**Results:** Several hypotheses were identified to explain increased concussion rates in female soccer players, these include, reduced neck strength/anthropometrics, increased head acceleration, increased ball-to-head concussions, differences in hormones and brain structure/function, and reduced visual awareness.

**Conclusion:** Promising ideas/reasons have been identified for increased concussion rates in female soccer players. Despite hypothesis generation there is scarce high-level evidence which is required to guide injury prevention and/or rule changes to protect female soccer players. The level of evidence for included studies is level 2–3 with most being observational cross-sectional or cohort studies.

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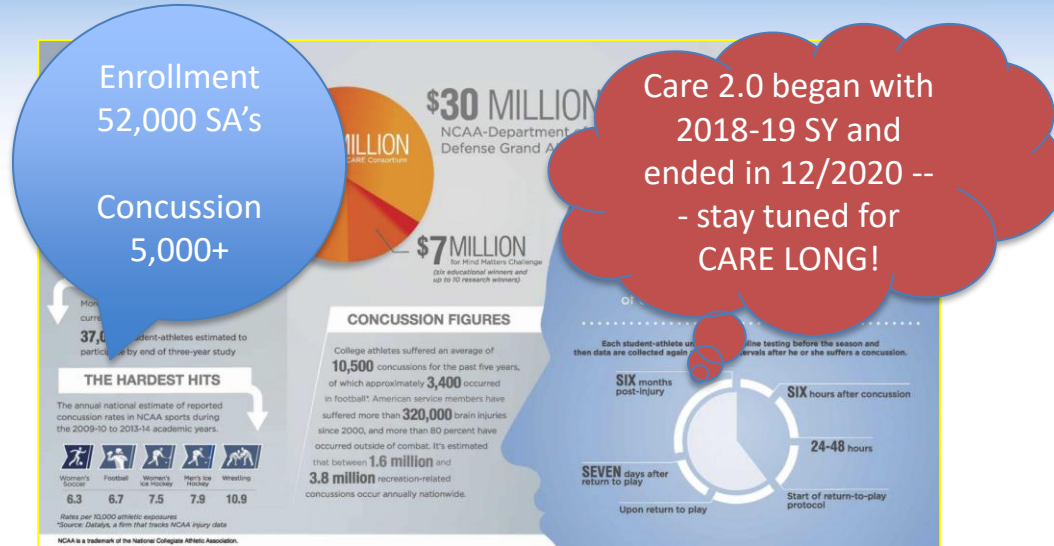


- The rate of concussion is greater in female soccer players when compared to males.
- Female soccer players have reduced neck strength and increased head acceleration.
- Females may suffer more concussions in relation to ball-to-head impact.
- There may be a hormonal link to increased concussion rates in female athletes.

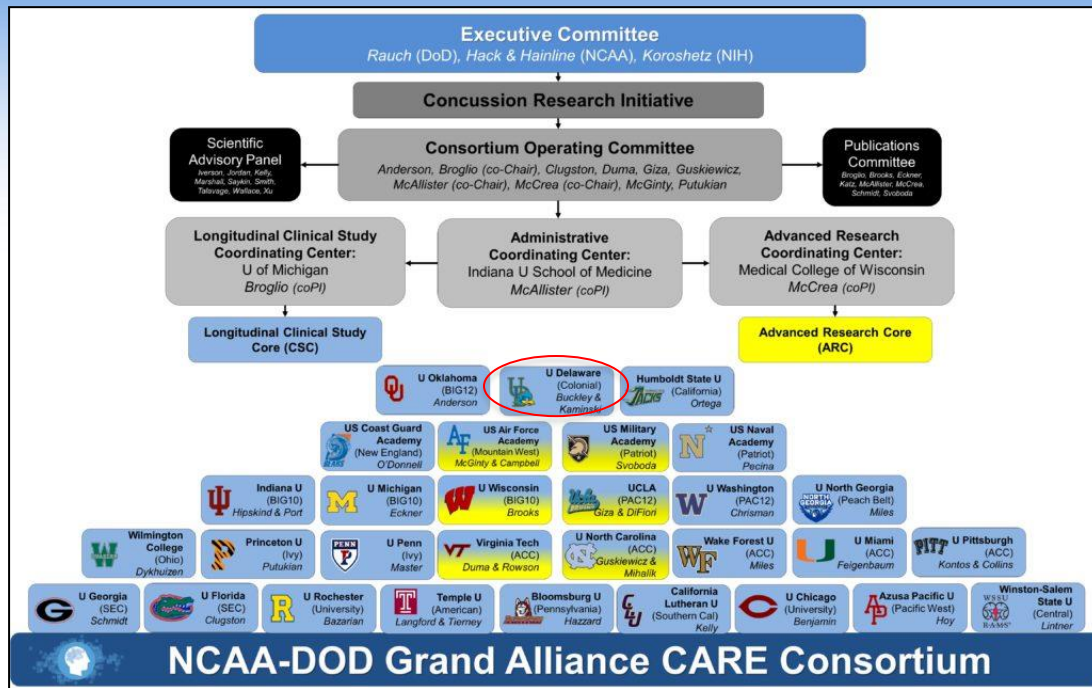
# The University of Delaware is Committed to Making Sports Participation SAFE, FUN, and ENJOYABLE!



# NCAA/DOD CARE Project



# Grand Alliance





## ORIGINAL RESEARCH ARTICLE

## A National Study on the Effects of Concussion in Collegiate Athletes and US Military Service Academy Members: The NCAA–DoD Concussion Assessment, Research and Education (CARE) Consortium Structure and Methods

Steven P. Broglio<sup>1</sup> · Michael McCrea<sup>2</sup> · Thomas McAllister<sup>3</sup> · Jaroslaw Harezlak<sup>4</sup> · Barry Katz<sup>5</sup> · Dallas Hack<sup>6</sup> · Brian Hainline<sup>6</sup> · CARE Consortium Investigators

### Abstract

**Background** The natural history of mild traumatic brain injury (TBI) or concussion remains poorly defined and no objective biomarker of physiological recovery exists for clinical use. The National Collegiate Athletic Association (NCAA) and the US Department of Defense (DoD) established the Concussion Assessment, Research and Education (CARE) Consortium to study the natural history of clinical and neurobiological recovery after concussion in the service of improved injury prevention, safety and medical care for student-athletes and military personnel.

**Objectives** The objectives of this paper were to (i) describe the background and driving rationale for the CARE

Consortium; (ii) outline the infrastructure of the Consortium policies, procedures, and governance; (iii) describe the longitudinal 6-month clinical and neurobiological study methodology; and (iv) characterize special considerations in the design and implementation of a multicenter trial.

**Methods** Beginning Fall 2014, CARE Consortium institutions have recruited and enrolled 23,533 student-athletes and military service academy students (approximately 90% of eligible student-athletes and cadets; 64.6% male, 35.4% female). A total of 1174 concussions have been diagnosed in participating subjects, with both concussion and baseline cases deposited in the Federal Interagency Traumatic Brain Injury Research (FITBIR) database.



# Video Summary of the Baseline Testing





# An Interesting Historical Quote vs. Contemporary Management of Concussions

- W. H. Earles, M.D. "The Necessity for More Care in the Treatment of Skull Fractures." *Journal of the American Medical Association*, July 18, 1903. 169

**NECESSITY FOR MORE CARE IN THE TREATMENT OF SKULL FRACTURES.\***  
W. H. EARLES, M.D.  
MILWAUKEE, WIS.

The substance of this paper is based on the following propositions:

  1. Fractures of the skull are not always recognized as such until too late to receive proper treatment.
  2. Fractures of the skull when not properly treated at or about the time of fracture, occasionally result in death, and if not in death in serious remote consequences.
  3. Fractures of the skull, when properly treated, usually terminate satisfactorily.

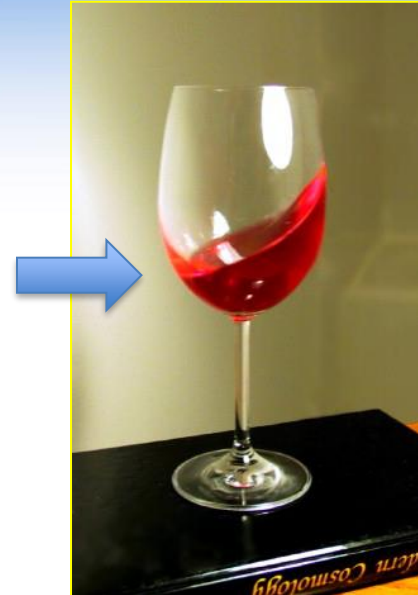
Every practitioner is aware that a large number of skull depressions, with their usual concomitants, are constantly forcing themselves on our attention. It is, we believe, right to assume that surgeons are familiar with the mischief that such depressions create, and would not knowingly allow them to remain were they recognized.

evidence of cerebral disturbances. These conclusions were verified in 52 cases through operation. Clinical reports of competent observers, coupled with everyday experiences, have clearly demonstrated that blows or falls on the head may cause serious trouble, both present and prospective, without producing fracture to the skull wall. If this be true, how much more likelihood is there of such conditions being present when fracture exists, especially if that fracture be depressed. It is on the effects of these injuries, rather than on the injuries themselves, that we would lay emphasis, and to invite attention to the necessity of a full and correct diagnosis at or about the time of injury, in order that either condition may be properly treated. Every case of recent head injury, however trivial it may appear, should, we believe, be treated with the greatest consideration, lest damage to hidden and important structures escape our attention, thus leaving a foundation for future trouble which too often is irreparable.

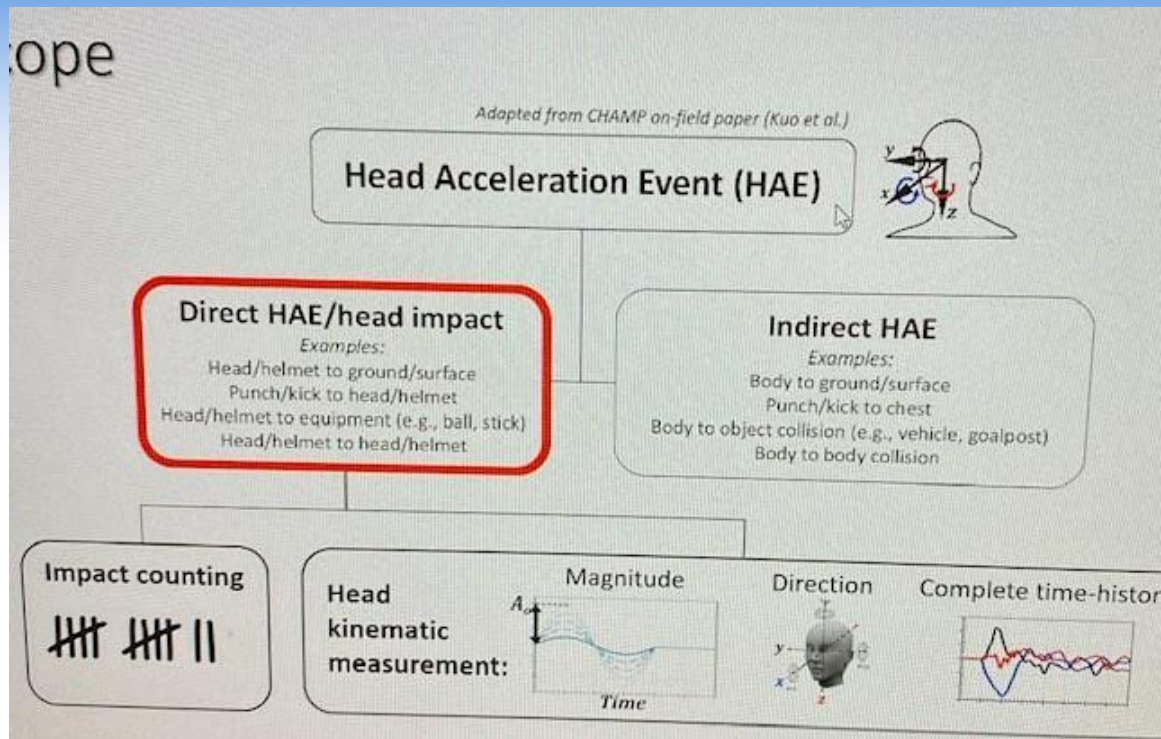
–What's the hurry? After all it is the brain!

# The Elephant in the Room

- Repetitive Subconcussive Head Impacts (RSHI)
  - Blows to the head which do not cause concussion signs and symptoms are hypothesized to cause clinical and pathological findings (“slosh” phenomenon)
    - Meehan et al, 2015.
  - Greatest effect through repetitive occurrences whereby cumulative exposure is deleterious
    - Bailes et al, 2013
  - “Probably.....genetic factors (APO E and IL-6) that play an important role in susceptibility to injury”
    - Bailes et al , 2013



# Consensus Head Acceleration Measurement Practices (CHAMP)



# Just How Many Headers Did Abby Wambach Have in Her 30 Year Career as a Soccer Player?

Senior career\*

**Apps** **(Gls)**

37 (23)

39 (21)

11 (9)

29 (17)

**116 (70)**

National team<sup>‡</sup>

2001–2015 [United States](#)

255 (184)

Would it be safe to say that she's headed the ball 10,000+ times during her 30+ year career?

- Youth?
- High School/Travel Team?
  - 4 years @ Our Lady of Mercy HS
  - 3 years with Rochester Spirit
- Collegiate (estimates)
  - Matches  $\approx 610 \div 77 = 7.9$
  - Practice  $\approx 190 \div 105 = 1.8$
- Professional (extrapolate)
  - Matches  $\approx 371 \times 7 = 2,597$  headers



# So What Does Her Brain Look Like Today? Into the Future?



Circa March 6, 2020



Photo credit: Boston University Center (Traumatic Encephalopathy)

# Did It Start With This?

## Chronic traumatic brain injury in professional soccer players

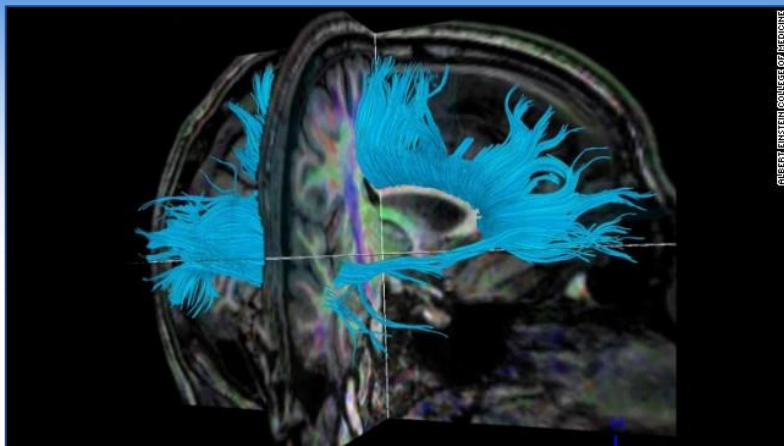
J.T. Matser, MSc; A.G.H. Kessels, MD; B.D. Jordan, MD; M.D. Lezak, PhD; and J. Troost, MD

**Article abstract**—*Objective:* To determine the presence of chronic traumatic brain injury in professional soccer players. *Methods:* Fifty-three active professional soccer players from several professional Dutch soccer clubs were compared with a control group of 27 elite noncontact sport athletes. All participants underwent neuropsychological examination. The main outcome measures were neuropsychological tests proven to be sensitive to cognitive changes incurred during contact and collision sports. *Results:* The professional soccer players exhibited impaired performances in memory, planning, and visuoperceptual processing when compared with control subjects. Among professional soccer players, performance on memory, planning, and visuoperceptual tasks were inversely related to the number of concussions incurred in soccer and the frequency of “heading” the ball. Performance on neuropsychological testing also varied according to field position, with forward and defensive players exhibiting more impairment. *Conclusion:* Participation in professional soccer may affect adversely some aspects of cognitive functioning (i.e., memory, planning, and visuoperceptual processing).

NEUROLOGY 1998;51:791–796



# It Has Continued With Headlines Like This



“Heading a Soccer Ball May be Bad for the Brain”

“Heading a Soccer Ball is Risky Even if Concussions Rare”

“Does Heading a Soccer Ball Cause Brain Damage?”

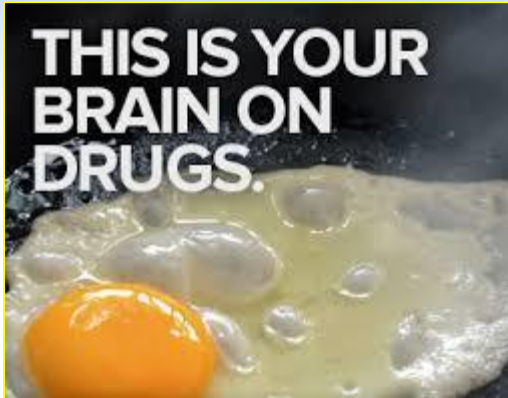
“Don’t Use Your Heads, Kids”

“Should Young Soccer Players be Banned from Heading the Ball?”

Patrick  
Grange



# This is Your Brain .....





International Journal of  
Pathology and Clinical Research

ISSN: 2469-5807

Gao et al. Int J Pathol Clin Res 2017, 3:050

DOI: 10.23937/2469-5807/1510050

Volume 3 | Issue 1

Case Report: Open Access

## Chronic Traumatic Encephalopathy-like Neuropathological Findings Without a History of Trauma

**Andrew F Gao<sup>1</sup>, David Ramsay<sup>2</sup>, Richelle Twose<sup>3</sup>, Ekaterina Rogaeva<sup>4</sup>, Charles Tator<sup>5,6</sup> and Lili-Naz Hazrati<sup>1,6,7\*</sup>**

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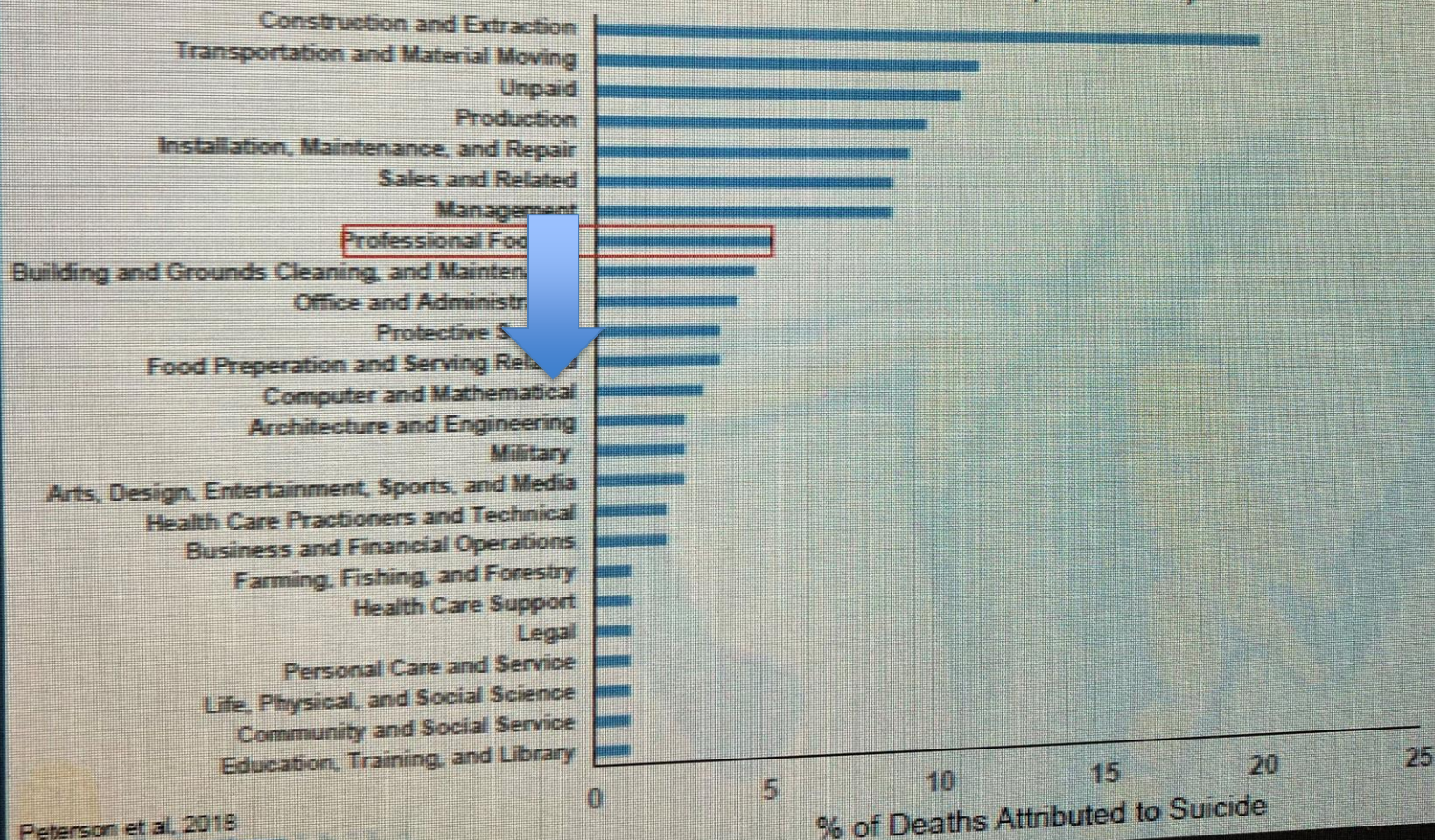
<sup>6</sup>Canadian Concussion Centre, Toronto Western Hospital, Toronto, ON, Canada

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# Average (%) of Deaths Attributed to Suicide (2012/2015)



Peterson et al, 2018

[www.bleachereport.com](http://www.bleachereport.com)

[www.pro-football-reference.com](http://www.pro-football-reference.com)



# The Latest Evidence

Bottomline is that playing American football past high school greatly increases your chances of developing CTE!



American Journal of Epidemiology  
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## Original Contribution

### Relationship Between Level of American Football Playing and Diagnosis of Chronic Traumatic Encephalopathy in a Selection Bias Analysis

Jessica LeClair, Jennifer Weuve, Matthew P. Fox, Jesse Mez, Michael L. Alosco, Chris Nowinski, Ann McKee, and Yorghos Tripodis\*

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*Initially submitted February 17, 2021; accepted for publication April 12, 2022.*

Chronic traumatic encephalopathy (CTE) is a neurodegenerative disease associated with exposure to repetitive head impacts such as those from American football. Our understanding of this association is based on research in autopsied brains, since CTE can only be diagnosed postmortem. Such studies are susceptible to selection bias, which needs to be accounted for to ensure a generalizable estimate of the association between repetitive head impacts and CTE. We evaluated the relationship between level of American football playing and CTE diagnosis after adjusting for selection bias. The sample included 290 deceased male former American football players who donated their brains to the Veterans Affairs–Boston University–Concussion Legacy Foundation (VA-BU-CLF) Brain Bank between 2008 and 2019. After adjustment for selection bias, college-level and professional football players had 2.38 (95% simulation interval (SI): 1.16, 5.94) and 2.47 (95% SI: 1.46, 4.79) times the risk of being diagnosed with CTE as high-school-level players, respectively; these estimates are larger than estimates with no selection bias adjustment. Since CTE is currently diagnosed only postmortem, we additionally provide plausible scenarios for CTE risk ratios for each level of play during the former players' lifetime. This study provides further evidence to support a dose-response relationship between American football playing and CTE.

# The FIELD Study



## OVERALL: **SUMMARY OF RESULTS**

The risk of neurodegenerative disease in former professional soccer players was previously unknown. Following the results of the FIELD study, we now have a more complete picture of lifelong health and dementia in soccer, greater than that of any other contact sport. Thus far, results from the FIELD study provide evidence of increased neurodegenerative disease in former professional soccer players, with risk shown to be greatest for **Defenders** players – specifically defenders, and those with longer career lengths. There were many health benefits also associated with a career in professional level soccer – lower risk of ischaemic heart disease, and respiratory cancer mortality, were seen in former players, as well as a lower risk of common mental health disorders, namely; anxiety and stress, depression, alcohol use, drug use, and bipolar and mood disorders.



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## Neurodegenerative Disease Mortality among Former Professional Soccer Players

Daniel F. Mackay, Ph.D., Emma R. Russell, M.Sc., Katy Stewart, Ph.D., John A. MacLean, M.B., Ch.B., Jill P. Pell, M.D., and William Stewart, M.B., Ch.B., Ph.D.

### ABSTRACT

#### BACKGROUND

Neurodegenerative disorders have been reported in elite athletes who participated in contact sports. The incidence of neurodegenerative disease among former professional soccer players has not been well characterized.

#### METHODS

We conducted a retrospective cohort study to compare mortality from neurodegenerative disease among 7676 former professional soccer players (identified from databases of Scottish players) with that among 23,028 controls from the general population who were matched to the players on the basis of sex, age, and degree of social deprivation. Causes of death were determined from death certificates. Data on medications dispensed for the treatment of dementia in the two cohorts were also compared. Prescription information was obtained from the national Prescribing Information System.

From the Institute of Health and Well-being (D.F.M., J.P.P.), the Institute of Neuroscience and Psychology (E.R.R., W.S.), and the Institute of Cardiovascular and Medical Sciences (K.S., J.A.M.), University of Glasgow, the Hampden Sports Clinic, Hampden Stadium (K.S., J.A.M.), and the Department of Neuropathology, Queen Elizabeth University Hospital (W.S.) — all in Glasgow, United Kingdom. Address reprint requests to Dr. Stewart at the Department of Neuropathology, Queen Elizabeth University Hospital, 1345 Govan Rd., Glasgow G51 4TF, United Kingdom, or at [william.stewart@glasgow.ac.uk](mailto:william.stewart@glasgow.ac.uk).

**RESULTS**

Over a median of 18 years, 1180 former soccer players (15.4%) and 3807 controls (16.5%) died. All-cause mortality was lower among former players than among controls up to the age of 70 years and was higher thereafter. Mortality from ischemic heart disease was lower among former players than among controls (hazard ratio, 0.80; 95% confidence interval [CI], 0.66 to 0.97;  $P=0.02$ ), as was mortality from lung cancer (hazard ratio, 0.53; 95% CI, 0.40 to 0.70;  $P<0.001$ ). Mortality with neurodegenerative disease listed as the primary cause was 1.7% among former soccer players and 0.5% among controls (subhazard ratio [the hazard ratio adjusted for competing risks of death from ischemic heart disease and death from any cancer], 3.45; 95% CI, 2.11 to 5.62;  $P<0.001$ ). Among former players, mortality with neurodegenerative disease listed as the primary or a contributory cause on the death certificate varied according to disease subtype and was highest among those with Alzheimer's disease (hazard ratio [former players vs. controls], 5.07; 95% CI, 2.92 to 8.82;  $P<0.001$ ) and lowest among those with Parkinson's disease (hazard ratio, 2.15; 95% CI, 1.17 to 3.96;  $P=0.01$ ). Dementia-related medications were prescribed more frequently to former players than to controls (odds ratio, 4.90; 95% CI, 3.81 to 6.31;  $P<0.001$ ). Mortality with neurodegenerative disease listed as the primary or a contributory cause did not differ significantly between goalkeepers and outfield players (hazard ratio, 0.73; 95% CI, 0.43 to 1.24;  $P=0.24$ ), but dementia-related medications were prescribed less frequently to goalkeepers (odds ratio, 0.41; 95% CI, 0.19 to 0.89;  $P=0.02$ ).

**CONCLUSIONS**

In this retrospective epidemiologic analysis, mortality from neurodegenerative disease was higher and mortality from other common diseases lower among former Scottish professional soccer players than among matched controls. Dementia-related medications were prescribed more frequently to former players than to controls. These observations need to be confirmed in prospective matched-cohort studies. (Funded by the Football Association and Professional Footballers' Association.)

This article was published on October 21, 2019, and updated on November 7, 2019, at NEJM.org.

N Engl J Med 2019;381:1801-8.

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What Happens When  
Soccer Bans Heading?  
Headline from “The  
Ringer” – April 2017

BioMechanics in  
Soccer

# What Does the Research Tell Us About Heading a Soccer Ball?

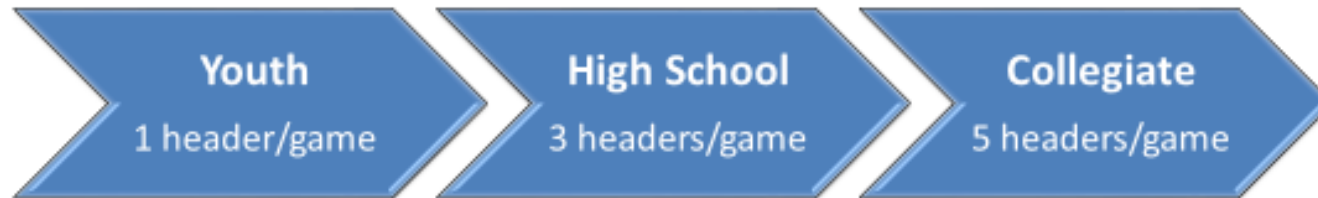


# Purposeful Soccer Heading Exposure



- Increases with age <sup>8,9</sup>
- Males 2x more likely to head the ball than females <sup>8,9</sup>
- Exposure in games > practices <sup>10</sup>

2021  
Wahlquist  
dissertation  
data



# Methods

## Weekend Youth Soccer Tournament

- Heading Exposure
- 60 Games

### U12

- 10 Female Games
- 10 Male Games

### U13

- 10 Female Games
- 10 Male Games

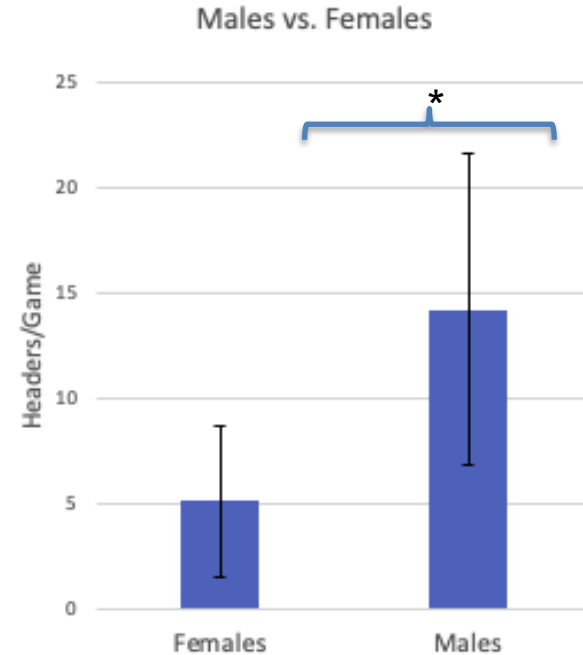
### U14

- 10 Female Games
- 10 Male Games



## Results: Males vs. Females

- N= 828 females & 846 males
- Males headed the ball significantly more than females: 14.2 vs 5.1 headers/game ( $p<.001$ )
- Large effect size,  $d=1.58$



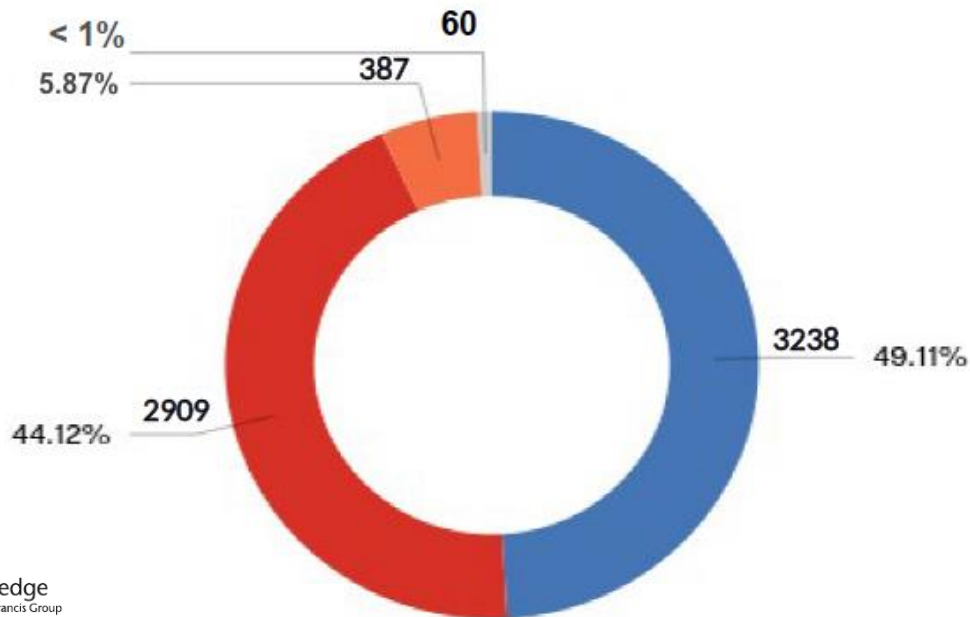
## ORIGINAL SURVEY RESEARCH

# Purposeful heading in U.S. youth soccer players: results from the U.S. soccer online heading survey – epidemiological evidence

## Original survey research

Thomas W. Kaminski<sup>a</sup>, George T. Chiampas<sup>b</sup>, Margot Putukian<sup>c</sup>, Donald Kirkendall<sup>d</sup>, Jennifer Fokas<sup>e</sup>  
and Anthony P. Kontos<sup>f,g</sup>

<sup>a</sup>Department of Kinesiology & Applied Physiology, Human Performance Laboratory, University of Delaware, Newark, DE, USA; <sup>b</sup>Emergency Medicine and Orthopaedic Surgery, Chief Medical Officer – U.S. Soccer, Northwestern University, Feinberg School of Medicine, Fuquay-Varina, NC, USA; <sup>c</sup>Director of Athletic Medicine, Princeton University, Princeton, NJ, USA; <sup>d</sup>James Urbanik Sport Sciences Institute, Duke Health, Durham, North Carolina; <sup>e</sup>College of Medicine, University of Michigan, Ann Arbor, MI, USA; <sup>f</sup>UPMC Sports Medicine Concussion Program, University of Pittsburgh, Pittsburgh, PA, USA; <sup>g</sup>Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, PA, USA



 None  1-10  11-20  21-30  31+

# High School (Interscholastic) Data

Research Quarterly for Exercise and Sport  
©2008 by the American Alliance for Health,  
Physical Education, Recreation and Dance  
Vol. 79, No. 2, pp.

## Examining the Relationship Between Purposeful Heading in Soccer and Computerized Neuropsychological Test Performance

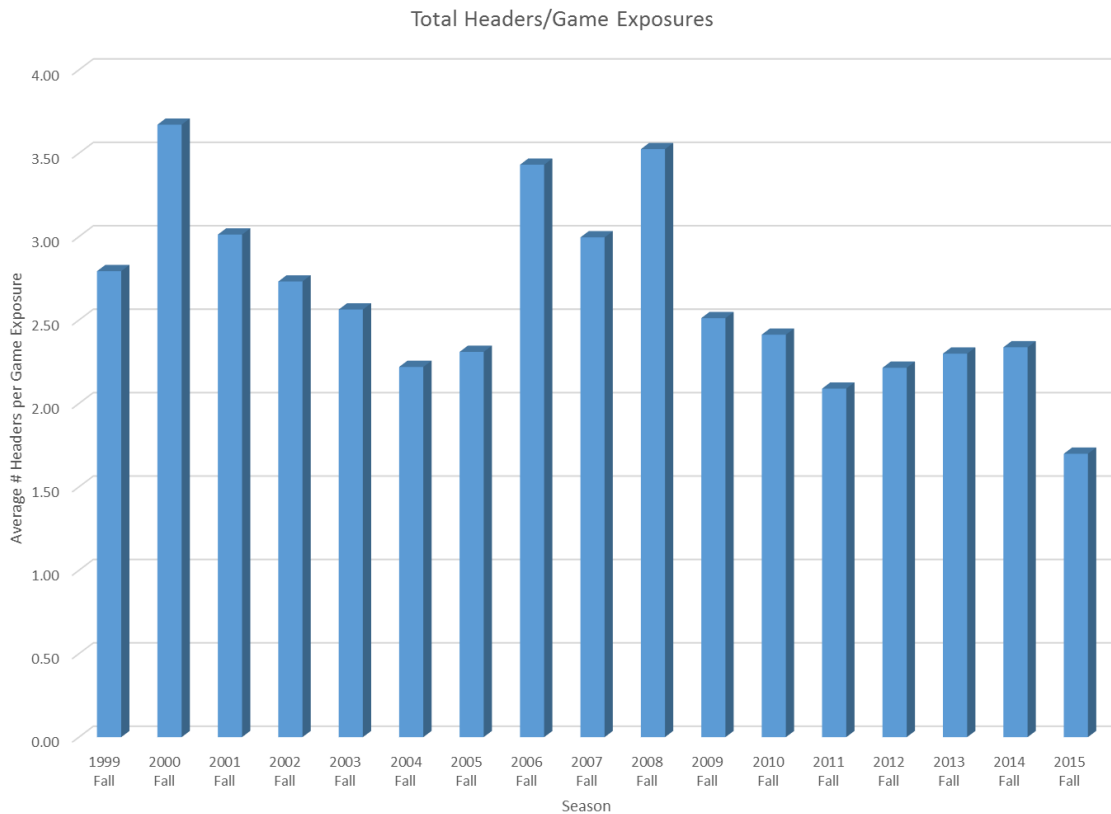
Thomas W. Kaminski, Eric S. Cousino, and Joseph J. Glutting

*The purpose of this study was to determine if a relationship exists between purposeful heading in soccer and neuropsychological test performance. Automated Neuropsychological Assessment Metrics throughput scores were derived on seven subset variables that measure a variety of neurocognitive abilities. Simple Spearman's rank correlations were calculated between headers per game (HPG) and the criterion variables. Interestingly, math processing speed (Spearman's  $\rho = .160$ ) and continuous performance test #2 ( $\rho = .124$ ) had small but significant correlations; both showed improvement in performance pre- to postseason. There were no significant correlations between HPG and the other five variables. This study found no detrimental relationship between the number of purposeful headers and the neurocognitive measures in this population.*

**Table 2.** Means and standard deviations for all predictors and criteria

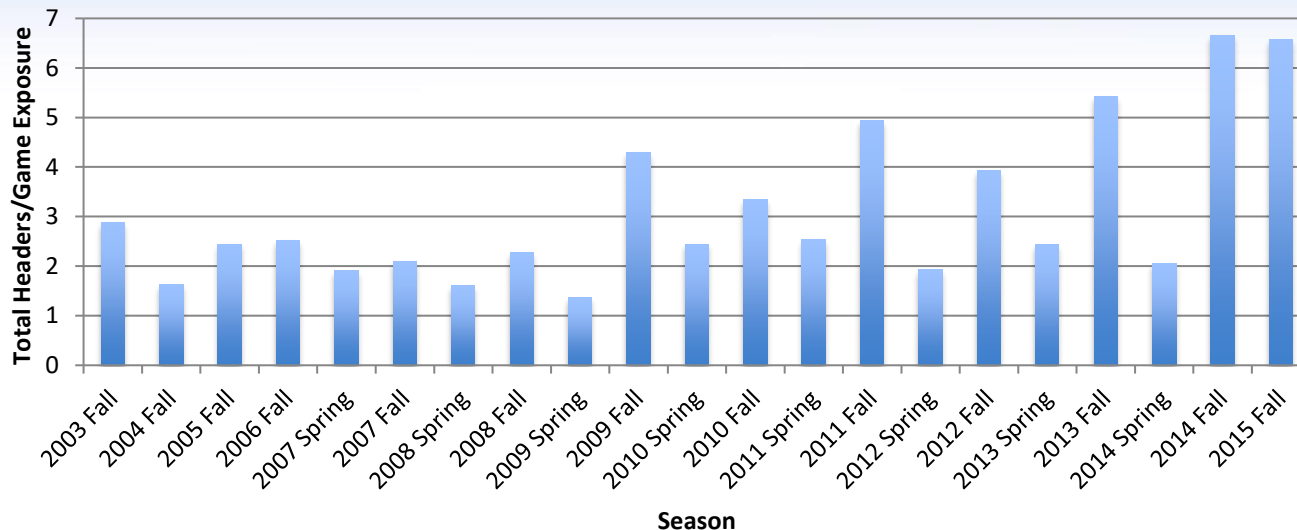
Variable	Mean	Standard deviation
Total headers	20.6	26.6
Total clear headers	7.8	11.3
Total pass headers	10.4	15.9
Total shot headers	1.2	2.7
Total deflection headers	2.5	3.6
Headers per game	1.0	1.3

# Soccer Heading in WSOC @ UD after 16 Years



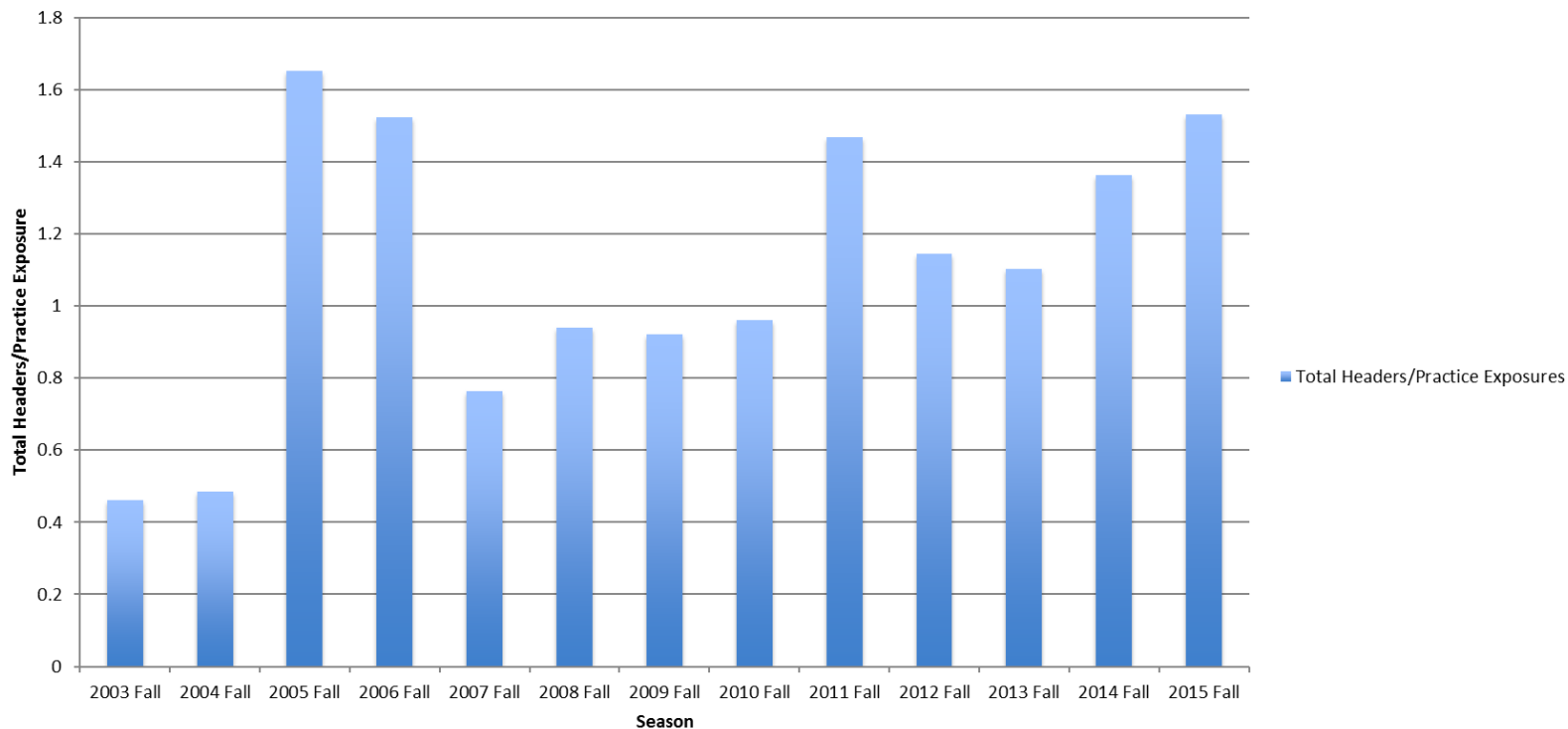
# Purposeful Heading Trends MSOC @ UD 2003-2015

## Total Headers/Game Exposures Men's Soccer 2003-2015



# Purposeful Heading Trends MSOC @ UD 2003-2015

Total Headers/Practice Exposures Men's Soccer 2003-2015






# Limited Data from Professional (male) Players

- Professional soccer players head the ball more than 2,000 times during their career
- 5,250 headers over a course of a 15-year career --- this equates to approximately 6.67 headers/game
- 16 headers per game by professional players; 8.5 per game by amateur players
- On average soccer players head the ball 6 times/game
- US National team (men) – 5 headers/game
- US Olympic Sports Festival – interviews with elite soccer players – 7.85 headers/game



## Head impact exposure in youth football—Are current interventions hitting the target?

Stian Bahr Sandmo<sup>1,2</sup>  | Thor Einar Andersen<sup>1</sup> | Inga Katharina Koerte<sup>3,4</sup> | Roald Bahr<sup>1</sup>

<sup>1</sup>Oslo Sports Trauma Research Center, Department of Sports Medicine, Norwegian School of Sport Sciences, Oslo, Norway

<sup>2</sup>Faculty of Medicine, University of Oslo, Oslo, Norway

<sup>3</sup>Department of Child and Adolescent Psychiatry, Psychosomatic, and Psychotherapy, Ludwig-Maximilians-University, Munich, Germany

<sup>4</sup>Department of Psychiatry, Psychiatry Neuroimaging Laboratory, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA

### Correspondence

Stian Bahr Sandmo, Oslo Sports Trauma Research Center, Department of Sports Medicine, Norwegian School of Sport Sciences, PB 4014 Ullevål Stadion, NO-0806 Oslo, Norway.  
Email: s.b.sandmo@nih.no

### Funding information

IRA-NET NEURON; The German Federal Ministry of Education and Research; The Research Council of Norway

Restrictions on heading in youth football have been implemented in some countries to limit head impact exposure. However, current interventions remain poorly guided by evidence. Our objective was to quantify heading exposure in youth football, assessing the effects of sex and age. Football matches played during an international youth football tournament with no heading restrictions were directly observed, including players from both sexes (11-19 years). The elite senior level was included for comparison, using video analysis. All heading events were registered, classified, and assigned to individual players. Heading rates were calculated for each sex and age group. We observed a total of 267 matches, corresponding to 4011 player hours (1927 player hours for females, 2083 player hours for males). Males headed more frequently than females (2.7 vs 1.8 headers/player hour;  $P < .001$ ). Heading rates increased with age (ANOVA,  $P < .001$ ), approaching the elite senior level for players 16 years and older. There was substantial variation within teams for all age and sex groups, with the widest range (1-18 headers) observed for girls aged 19. Girls younger than 12 years had the lowest exposure, with an average of <2 players per team heading the ball, each with 1-2 headers. In conclusion, age and sex influence head impact exposure in youth football, and warrants careful consideration when introducing injury prevention measures. Males are more frequently exposed than females, heading rates increase with age, and there is substantial variation between players. Heading is a rare event in the youngest age groups, especially among females.

### KEYWORDS

concussion, epidemiology, repetitive, soccer, subconcussive, TBI

**TABLE 1** Number of observed matches, player hours, heading events, and head impact incidents according to age and sex during an international youth football tournament in Norway

Level	Boys				Girls			
	Matches (n)	Player hours	Headers (n)	Incidents (n)	Matches (n)	Player hours	Headers (n)	Incidents (n)
U-12	16	112	138	0	12	84	53	0
U-13	33	231	423	2	28	196	178	0
U-14	21	252	562	0	12	144	77	1
U-15	17	249	565	0	14	205	293	0
U-16	10	183	432	1	12	220	411	1
U-17	18	330	1079	3	12	220	495	0
U-18	6	132	405	0	14	308	536	1
U-20	12	264	855	4	10	220	534	2
Senior*	10	330	1127	9	10	330	886	6

\*Senior level was observed from TV video recordings from the Norwegian premier leagues (Toppserien and Eliteserien), and included for comparison.



## Recent and Long-Term Soccer Heading Exposure Is Differentially Associated With Neuropsychological Function in Amateur Players

Cara F. Levitch,<sup>1</sup> Molly E. Zimmerman,<sup>1,2</sup> Naomi Lubin,<sup>2,3</sup> Namhee Kim,<sup>2,3</sup> Richard B. Lipton,<sup>4,5</sup> Walter F. Stewart,<sup>6</sup> Mimi Kim,<sup>5</sup> AND Michael L. Lipton<sup>2,3,7,8</sup>

<sup>1</sup>Fordham University, Department of Psychology, Bronx, New York  
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<sup>7</sup>Albert Einstein College of Medicine and Montefiore Medical Center, Department of Psychiatry & Behavioral Sciences, Bronx, New York  
<sup>8</sup>The Dominick P. Purpura Department of Neuroscience, Albert Einstein College of Medicine and Montefiore Medical Center, Bronx, New York

(RECEIVED February 24, 2017; FINAL REVISION July 6, 2017; ACCEPTED July 10, 2017; FIRST PUBLISHED ONLINE August 22, 2017)

### Abstract

**Objectives:** The present study examined the relative contribution of recent or long-term heading to neuropsychological function in amateur adult soccer players. **Participants and Methods:** Soccer players completed a baseline questionnaire (HeadCount-12m) to ascertain heading during the prior 12 months (long-term heading, LTH) and an online questionnaire (HeadCount-2w) every 3 months to ascertain heading during the prior 2 weeks (recent heading, RH). Cogstate, a battery of six neuropsychological tests, was administered to assess neuropsychological function. Generalized estimating equations were used to test if LTH or RH was associated with neuropsychological function while accounting for the role of recognized concussion. **Results:** A total of 311 soccer players completed 630 HeadCount-2w. Participants had an average age of 26 years. Participants headed the ball a median of 611 times/year (mean = 1,384.03) and 9.50 times/2 weeks (mean = 34.17). High levels of RH were significantly associated with reduced performance on a task of psychomotor speed ( $p = .02$ ), while high levels of LTH were significantly associated with poorer performance on tasks of verbal learning ( $p = .03$ ) and verbal memory ( $p = .04$ ). Significantly better attention ( $p = .02$ ) was detectable at moderately high levels of RH, but not at the highest level of RH. One hundred and seven (34.4%) participants reported a lifetime history of concussion, but this was not related to neuropsychological function and did not modify the association of RH or LTH with neuropsychological function. **Conclusion:** High levels of both RH and LTH were associated with poorer neuropsychological function, but on different domains. The clinical manifestations following repetitive exposure to heading could change with chronicity of exposure. (*JINS*, 2018, 24, 147–155)

**Keywords:** Brain injury. Sport. Cognitive impairment. Soccer. Heading. Repetitive head trauma

Correspondence:  
Dr. Lipton  
Michael L.

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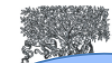
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# Alarming New Evidence About Soccer Heading?

EBIUM-00835; No of Pages 6

EBiomedicine xxx (2016) xxx–xxx

Contents lists available at ScienceDirect



Discussion: Sub-concussive head impacts routine in soccer heading are associated with immediate, measurable electrophysiological and cognitive impairments. Although these changes in brain function were transient, these effects may signal direct consequences of routine soccer heading on (long-term) brain health which requires further study.

Sports  
Transcranial magnetic stimulation  
Sub-concussion  
Traumatic brain injury

Results: Immediately following heading an increase in corticomotor inhibition was detected; further to these electrophysiological alterations, measurable reduction memory function were also found. These acute changes appear transient, with values normalizing 24 h post-heading.

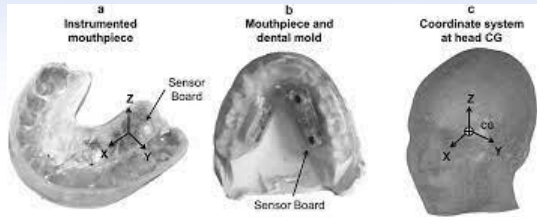
Discussion: Sub-concussive head impacts routine in soccer heading are associated with immediate, measurable electrophysiological and cognitive impairments. Although these changes in brain function were transient, these effects may signal direct consequences of routine soccer heading on (long-term) brain health which requires further study.

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# Technological Advances to QUANTITATIVELY Track and Monitor Head Impacts in Soccer (and other sports)



# Wake Forest Collaboration



**Examining Repetitive  
Head Impacts in Collegiate  
Soccer Players Using a  
Custom Retainer  
Mouthpiece Sensor**

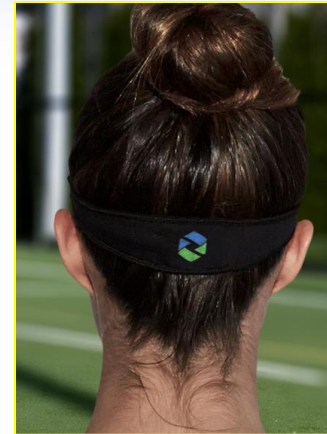
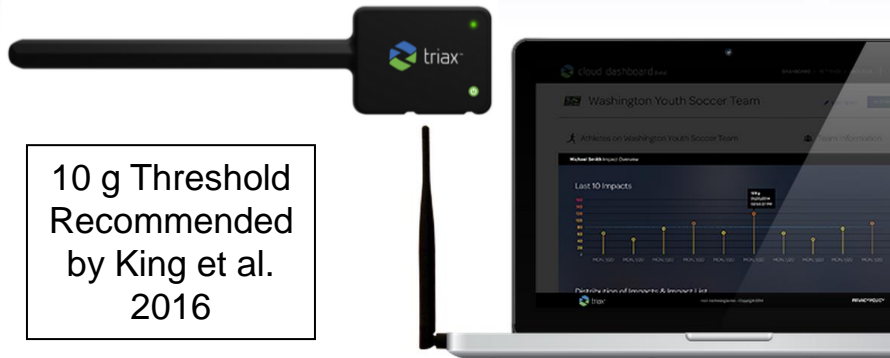




# Mouthpiece Sensors and RHI



# Using Triaxial Accelerometers to Monitor Real-Time RHI





# Linear Acceleration in Direct Head Contact Across Impact Type, Player Position, and Playing Scenario in Collegiate Women's Soccer Players

Lindsey C. Lamond, MS\*; Jaclyn B. Caccese, PhD\*;  
Thomas A. Buckley, EdD, ATC\*; Joseph Glutting, PhD†;  
Thomas W. Kaminski, PhD, ATC, FNATA, FACSM\*

\*Department of Kinesiology and Applied Physiology and †School of Education, University of Delaware, Newark

**Context:** Heading, an integral component of soccer, exposes athletes to a large number of head impacts over a career. The literature has begun to indicate that cumulative exposure may lead to long-term functional and psychological deficits. Quantifying an athlete's exposure over a season is a first step in understanding cumulative exposure.

**Objective:** To measure the frequency and magnitude of direct head impacts in collegiate women's soccer players across impact type, player position, and game or practice scenario.

**Design:** Cross-sectional study.

**Setting:** National Collegiate Athletic Association Division I institution.

**Patients or Other Participants:** Twenty-three collegiate women's soccer athletes.

**Main Outcome Measure(s):** Athletes wore Smart Impact Monitor accelerometers during all games and practices. Impacts were classified during visual, on-field monitoring of athletic events. All direct head impacts that exceeded the 10g threshold were included in the final data analysis. The dependent variable was linear acceleration, and the fixed effects were (1) type of impact: clear, pass, shot, unintentional deflection, or head-to-

head contact; (2) field position: goalkeeper, defense, forward, or midfielder; (3) playing scenario: game or practice.

**Results:** Shots ( $32.94g \pm 12.91g$ ,  $n = 38$ ;  $P = .02$ ) and clears ( $31.09g \pm 13.43g$ ,  $n = 101$ ;  $P = .008$ ) resulted in higher mean linear accelerations than passes ( $26.11g \pm 15.48g$ ,  $n = 451$ ). Head-to-head impacts ( $51.26g \pm 36.61g$ ,  $n = 13$ ;  $P < .001$ ) and unintentional deflections ( $37.40g \pm 34.41g$ ,  $n = 24$ ;  $P = .002$ ) resulted in higher mean linear accelerations than purposeful headers (ie, shots, clears, and passes). No differences were seen in linear acceleration across player position or playing scenario.

**Conclusions:** Nonheader impacts, including head-to-head impacts and unintentional deflections, resulted in higher mean linear accelerations than purposeful headers, including shots, clears, and passes, but occurred infrequently on the field. Therefore, these unanticipated impacts may not add substantially to an athlete's cumulative exposure, which is a function of both frequency and magnitude of impact.

**Key Words:** repetitive head impacts, subconcussive head impacts, impact exposure, concussions

# Influences on Head Acceleration in Soccer

- Low head-neck segment mass, ↑ head acceleration
- Head-neck-torso alignment, ↓ head acceleration
- Neck strength and stiffness, ↓ head acceleration
- Head-to-head impacts and unanticipated ball contacts, ↑ head acceleration
- Ball contacts at high velocity, ↑ head acceleration
- Headgear, ↓ head acceleration, but may also cause athletes to play more recklessly because they feel a sense of increased security

# Importance to Profes

- Purposeful heading is an important and vital skill in soccer!
- Sensors are a good tool to help us study and monitor head impacts in soccer --- however they likely require video verification backup!
- Using sensors allow us to make comparisons.
- Heading in soccer, when done properly, may not be bad.
- Downstream effects? Concern about future national team players who are not very good at heading the ball?



## Video Confirmation of Head Impact Sensor Data From High School Soccer Players

Declan A. Patton,<sup>\*†</sup> PhD, Colin M. Huber,<sup>†‡</sup> BS, Catherine C. McDonald,<sup>†§</sup> PhD, Susan S. Margulies,<sup>||</sup> PhD, Christina L. Master,<sup>†¶</sup> MD, and Kristy B. Arbogast,<sup>†#</sup> PhD  
*Investigation performed at the Children's Hospital of Philadelphia, Philadelphia, Pennsylvania, USA*

**Background:** Recent advances in technology have enabled the development of head impact sensors, which provide a unique opportunity for sports medicine researchers to study head kinematics in contact sports. Studies have suggested that video or observer confirmation of head impact sensor data is required to remove false positives. In addition, manufacturer filtering algorithms may be ineffective in identifying true positives and removing true negatives.

**Purpose:** To (1) identify the percentage of video-confirmed events recorded by headband-mounted sensors in high school soccer through video analysis, overall and by sex; (2) compare video-confirmed events with the classification by the manufacturer filtering algorithms; and (3) quantify and compare the kinematics of true- and false-positive events.

**Study Design:** Cohort study; Level of evidence, 2.

**Methods:** Adolescent female and male soccer teams were instrumented with headband-mounted impact sensors (SIM-G; Triax Technologies) during games over 2 seasons of suburban high school competition. Sensor data were sequentially reduced to remove events recorded outside of game times, associated with players not on the pitch (ie, field) and players outside the field of view of the camera. With video analysis, the remaining sensor-recorded events were identified as an impact event, trivial event, or nonevent. The mechanisms of impact events were identified. The classifications of sensor-recorded events by the SIM-G algorithm were analyzed.

**Results:** A total of 6796 sensor events were recorded during scheduled varsity game times, of which 1893 (20%) were sensor-recorded events associated with players on the pitch in the field of view of the camera during verified game times. Most video-confirmed events were impact events (n = 1316, 70%), followed by trivial events (n = 396, 21%) and nonevents (n = 181, 10%). Female athletes had a significantly higher percentage of trivial events and nonevents with a significantly lower percentage of impact events. Most impact events were head-to-ball impacts (n = 1032, 78%), followed by player contact (n = 144, 11%) and falls (n = 129, 10%) with no significant differences between male and female teams. The SIM-G algorithm correctly identified 70%, 52%, and 66% of video-confirmed impact events, trivial events, and nonevents, respectively.

**Conclusion:** Video confirmation is critical to the processing of head impact sensor data. Percentages of video-confirmed impact events, trivial events, and nonevents vary by sex in high school soccer. Current manufacturer filtering algorithms and magnitude thresholds are ineffective at correctly classifying sensor-recorded events and should be used with caution.

**Keywords:** head injuries/concussion; pediatric sports medicine; football (soccer); injury prevention



# US Soccer Youth Heading Guidelines

- In 2015, guidelines governing purposeful heading in youth populations were implemented
- Players 10 years and younger
  - Banned
- Players 11-13 years old
  - Unlimited heading in games and practices
  - Limited to 15-20 headers in practice/week
- Players 14 years and older
  - Unlimited heading in games and practices

This was in response  
to a class-action  
lawsuit from parents  
in California!



# Youth Soccer Heading Videos



# The English Football Association Guidelines



For ALL

## HEADING GUIDANCE

### HEADLINES:

- No heading in training in the foundation phase
- Graduated approach to heading for child development phase U12-U16
- U18 heading drills should be reduced, to take into consideration the heading exposure in matches
- Don't over inflate the footballs: use the lowest pressure authorised by the Laws of the Game

This was in response to good scientific/medical evidence!

### Heading frequency

Heading should not be introduced in training sessions at this age

Heading remains a low priority – 1 session per month max 5 headers

Heading remains a low priority – 1 session per week & max 5 headers

Heading remains a low priority – 1 session per week & max 10 headers

U18

Heading drills should be reduced as far as possible, taking into consideration the heading exposure in matches

## Collaboration with Einstein Medical Center – Dr. Michael Lipton (Gruss Magnetic Resonance Research Center [MRRC])

- Examining the mitigating effects of EXERCISE (VO<sub>2</sub> max) in establishing brain resiliency to RHI!
- \$5 million/5 years



National Institute of  
Neurological Disorders  
and Stroke



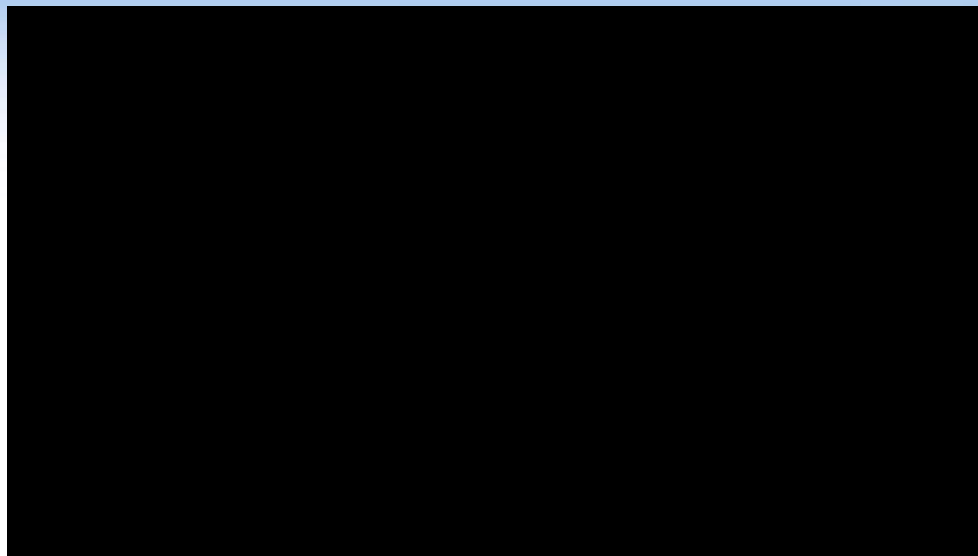


## Introducing “Get aHEAD Safely in Soccer”™

[https://unitedsoccercoaches.org/web/web/Education/eLearning/Get aHEAD Safely in Soccer.aspx](https://unitedsoccercoaches.org/web/web/Education/eLearning/Get%20aHEAD%20Safely%20in%20Soccer.aspx)



# **“Get aHEAD Safely in Soccer”™**



# Examining RHI in Youth Soccer Players



# Teaching Heading as a Skill



**Watch the overzealous dad getting his 3 y.o. daughter to head a ball ---- ouch!!**

- “Age 9, 10, and 11 might be the Golden Age of Learning, but it is not the Golden Age of Heading” - Howe & Waiters
- Coaches must be careful when and how to correctly teach proper heading methods

# The Craziiness of Ill-Informed Coaches Continues even at the Intercollegiate Level!

March 2, 2022

A new lawsuit in the US District Court for the Western District of Texas alleges that former Baylor women's soccer head coach Paul Jobson forced players to go through repeated header drills using a ball machine and as a result of that abuse the plaintiff, Eva Mitchell, has suffered brain injuries traumatic enough that for the past 18 months she has been unable to function independently.

Mitchell's counsel, attorneys Jason Luckasevic and Robert Stem, filed the complaint on Mitchell's behalf on Wednesday. Mitchell's story is a cautionary one for all college athletes but especially for those who play soccer and identify as women. Information about the risks of brain trauma for such athletes shows such women face elevated risks in sport.

## Mitchell alleges that former coach improperly used machine in header drills

According to the press release from Luckasevic's firm (Goldberg, Persky & White of Pittsburgh, Pa.), Mitchell was subjected to "repeated and dangerous header drills in practice." Perhaps the most egregious of her allegations about Jobson was his use of a ball machine in drills.



# Decreasing the Risk of Concussion in Soccer

- Teach proper heading techniques
  - *↑ the effective mass of the player via proper technique whereby the trunk/neck/head become 1!*
- Develop strong neck musculature
- Teach EYES OPEN concept (visual training implications?)
- Avoid dangerous play situations
  - Coaches should take time to talk to young soccer athletes about this
- Referees who enforce the rules and guidelines
- Use softer/under-inflated soccer balls (especially in the youth players)
- Developing children DO NOT need to be heading the ball!



<http://thetrainingtriangle.com/>

# So Should I Care about RHI in Football (Soccer)?

- Prudent and judicious use of purposeful heading drills in youth soccer players ---- are the US Soccer youth heading guidelines appropriate?
  - Validity of programs such as the Get aHEAD Safely in Soccer are needed!
- Aerial challenges pose the most significant concussion threat in soccer/football and steps taken to protect players are needed
  - Awareness and “personal space” are critical for protection
- Data from the Einstein Soccer Study are pointing toward a heading threshold point that may unlock the answers to long-term exposure issues



# Future Research

- Impact of a ball on the head, including examination of ball pressures in game
- Verify the exposure to heading across all ages
- Longitudinal studies on soccer players focusing on exposure and injury
- Determine the minimum safe age to begin heading the ball.
- Importance of neck strengthening in soccer



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# Questions





## CONTACT INFORMATION



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Get aHEAD Safely in Soccer— Online Diploma Course -

<https://unitedsoccercoaches.org/education/get-ahead-safely-in-soccer/>

# Thank You



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