



Portrait of Denny-Brown from Queen Square collection  
A BUSM Tradition

# A Subconcussive Load Effect & Trauma Profile for Chronic Traumatic Encephalopathy: A Meta-analysis of New Trends

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## BACKGROUND

•Visits to the ER for mild Traumatic Brain Injury (mTBI/Concussions) have risen by 62% within the last decade. The CDC considers improved awareness and sensitivity as possible explanations. Imaging techniques such as DTI & fMRI, coupled with genetic assays and novel biomarkers allows for diagnosis of certain diseases sometimes years before disease onset has even begun. Recent technological advancements have provided a means to study biomechanical variables in sport related head impacts. Yet despite such improvements, too little is known about the neurologic sequelae of such repetitive head impacts to the brain. It should not be too surprising then that public health concerns over mild, asymptomatic repetitive impacts has intensified as new accounts of brain changes are being found in students who not only are the standard measures of cognitive surveillance, but also report no history of concussions or symptoms.

•Subconcussive trauma is defined by impacts that are asymptomatic but perhaps accumulate. Levenz et al used neurocognitive testing and functional MRI to find measurable neurocognitive abnormalities.

•A growing number of unique CTE-confirmed cases have been found: a battered wife, an autistic person displaying a repetitive head banging behavior, our military servicemen and women, and even teenagers like Owen Thomas, a UPenn student who by all accounts lacked any identifiable concussion history.

•There exists a need to further investigate subconcussive trauma and its link to Chronic Traumatic Encephalopathy (CTE).

## An Evidenced Based Review

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## METHODS & AIMS

### Meta-Trend Graph

-To determine if an inter-sport threshold exists

-To determine if subconcussive trauma can be characterized as "cumulative."

-Offers important solutions to current debates

### Pooled Review of Post-Mortem Case Studies

-To analyze differences in symptoms and death between football players and boxers

-Students T-test is used but unadjusted for cause of death

### Concept Matrix

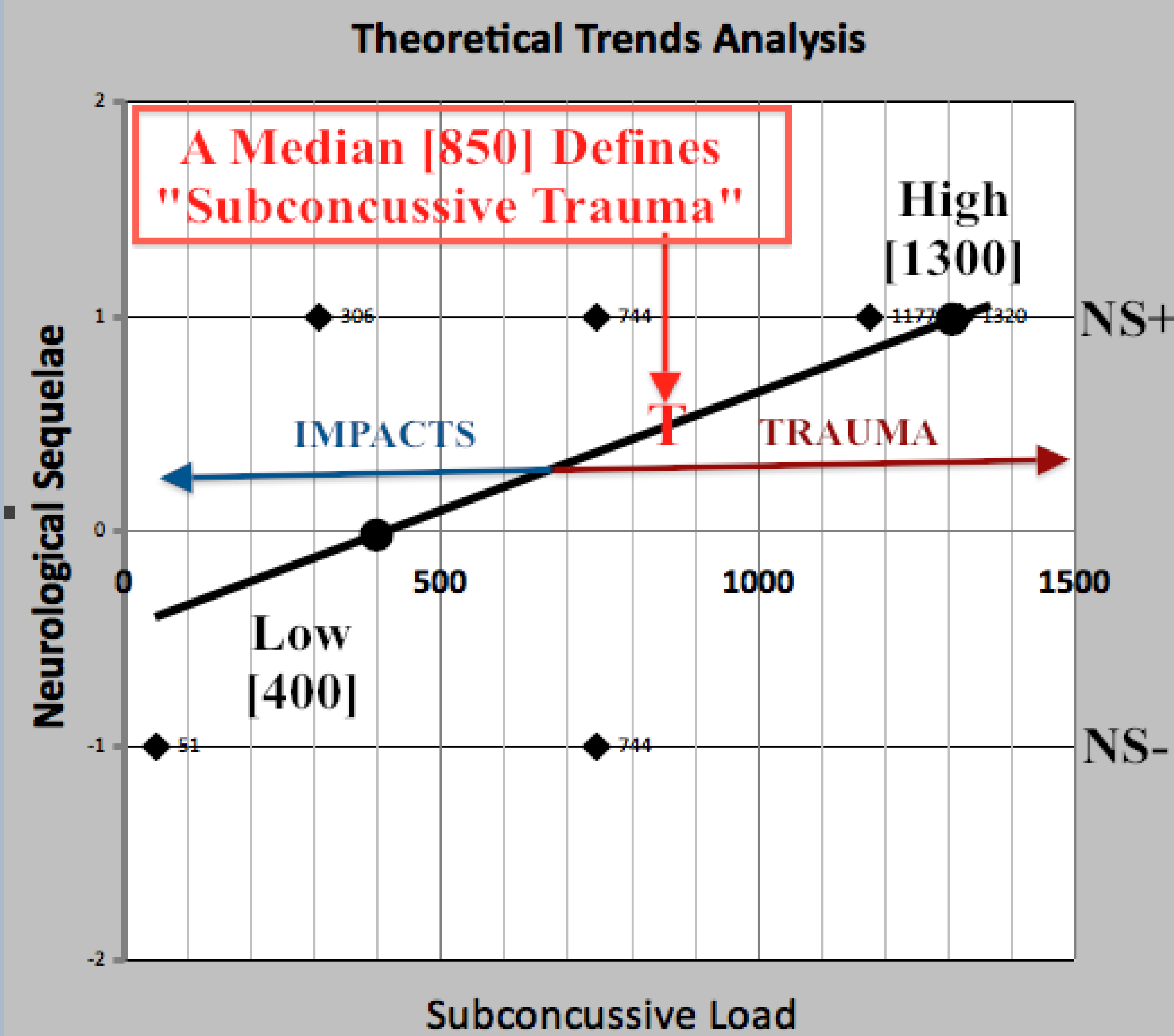
-To determine inter-sport trends

-To determine if a common impact profile exists

### A Novel Soccer Cohort

-To define high exposure by position & heading technique

## META-TREND GRAPH



### An Evidenced Based Definition of Subconcussive Trauma: Impact Loads > 850

Inclusion Criteria: The age or level of the participants involved must not have been obscured. Each study must have provided a total seasonal hit count, or been easily attributed a HIT count.

Discussion: 400 is considered lower risk and 1300 higher risk. From this graph it is reasonable to label "Subconcussive Impacts" above 850 (our theoretical median of +neurological sequelae). Sports that do not track HIT count should collect this data and consider adopting this inter-sport threshold.

Limitations: This is a theoretical model only based on published HIT data.

## POOLED CASE REVIEW ANALYSIS ON EARLY CTE SYMPTOMS

	Football Players†	Boxers †	P-Value
Age of Death	41.9 (37.5, 46.2)	61.0 (57.3, 64.6)	<0.0001‡
Total Years Played	16.6 (13.1, 20.1)	15.0 (13.2, 16.8)	0.43
Age of Symptom Onset	42 (33.5, 50.5)	45.2 (39.9, 50.4)	0.46
Years Between Retirement from Sports and Symptoms Onset	7.3 (-0.1, 24.8)	10.3 (5.1, 15.5)	0.45
Years Between Symptom Onset and Death	7.7 (5.0, 10.4)	18.9 (14.2, 23.6)	0.006‡

\*Values presented as mean  
† Values in parentheses represent 95% confidence intervals  
‡ P values for difference in means <0.05 considered significant

**Results:** The mean ages of death in CTE cases were 41.9 and 61.0 for football players and boxers, respectively (P<0.0001). The mean number of years from symptom onset to death was 7.7 and 18.9 for football players and boxers, respectively (P=0.007).

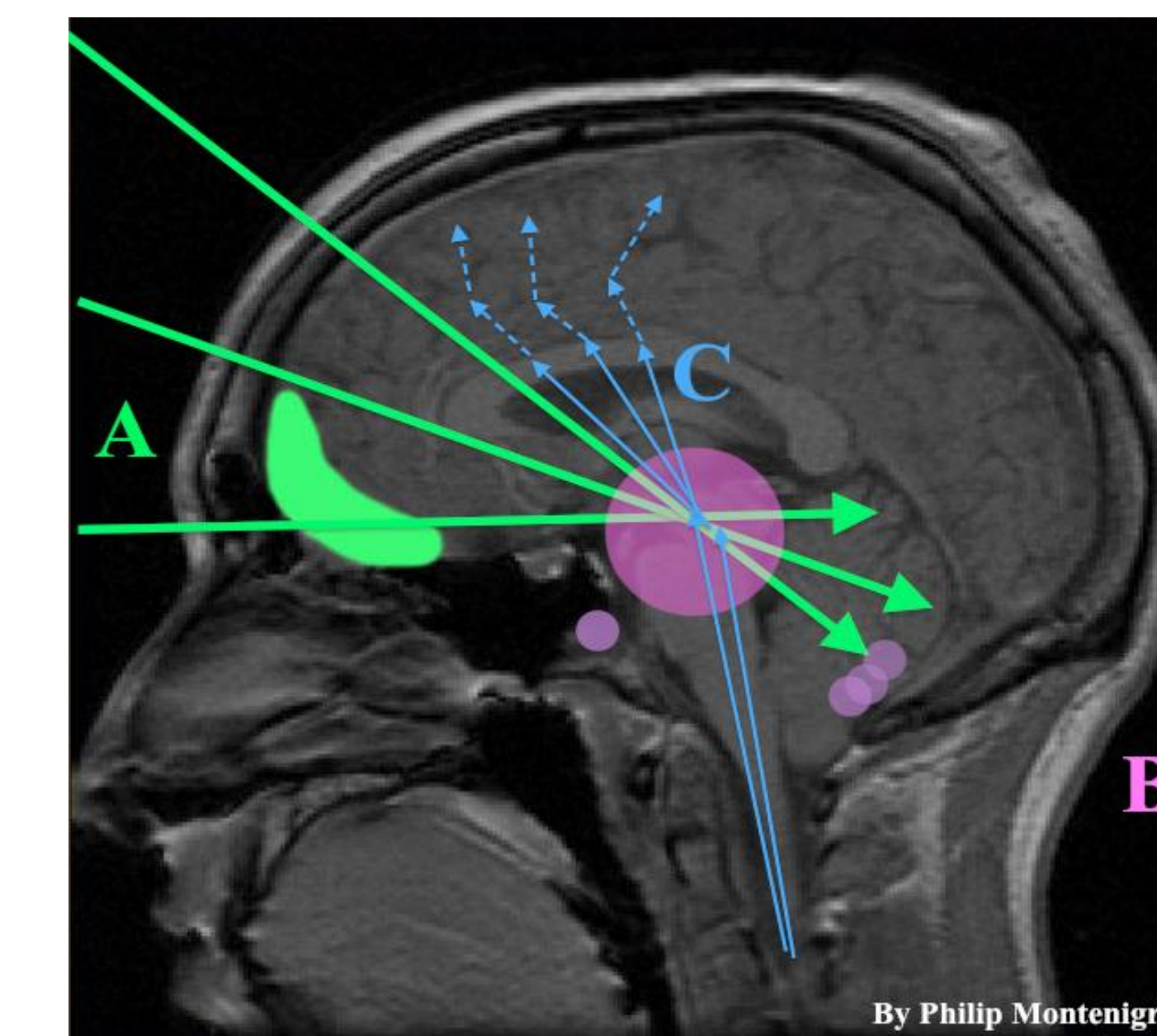
**Limitations:** This is a limited retrospective analysis of the data available on published case studies; unadjusted for cause of death (data not available in most cases).

## CONCEPT MATRIX-IMPACT PROFILE & NEUROPATHOLOGY

Matrix .1	Boxing	Football	Soccer
Concussion Incidence	Rotational -71.2g -	Translational	Translational
Subconcussive Exposure	Number/Total Bout Time		20g
Most Frequent Impact Location	Front A	Front A	Front A "Standard Header"
Subconcussive Impact Location	Front A	Front A	Front A
High Exposure is Subconcussive	Total Bout & # Bouts (not TKO's)	SCTrauma > 850	SCTrauma > 850
Delayed Midbrain Response	Mid Brain Shearing	Mid Brain Shearing	Mid Brain Shearing
Dose-Threshold Response	Changes on EEG	fMRI Preliminary analysis	DTI > 1300 (Lipton 2012)
Age / Level - earliest exposure	Mid-Teens(+/-)	Age 5	Age 5
Seasonal Average SC Exposure	Steadily Declining (reduced bouts)	Lineman>Tight Ends>Running Backs	Central Mid Field & Central Back
Confirmed Postmortem CTE	YES	YES	YES

### [ACUTE] Impact Profile:

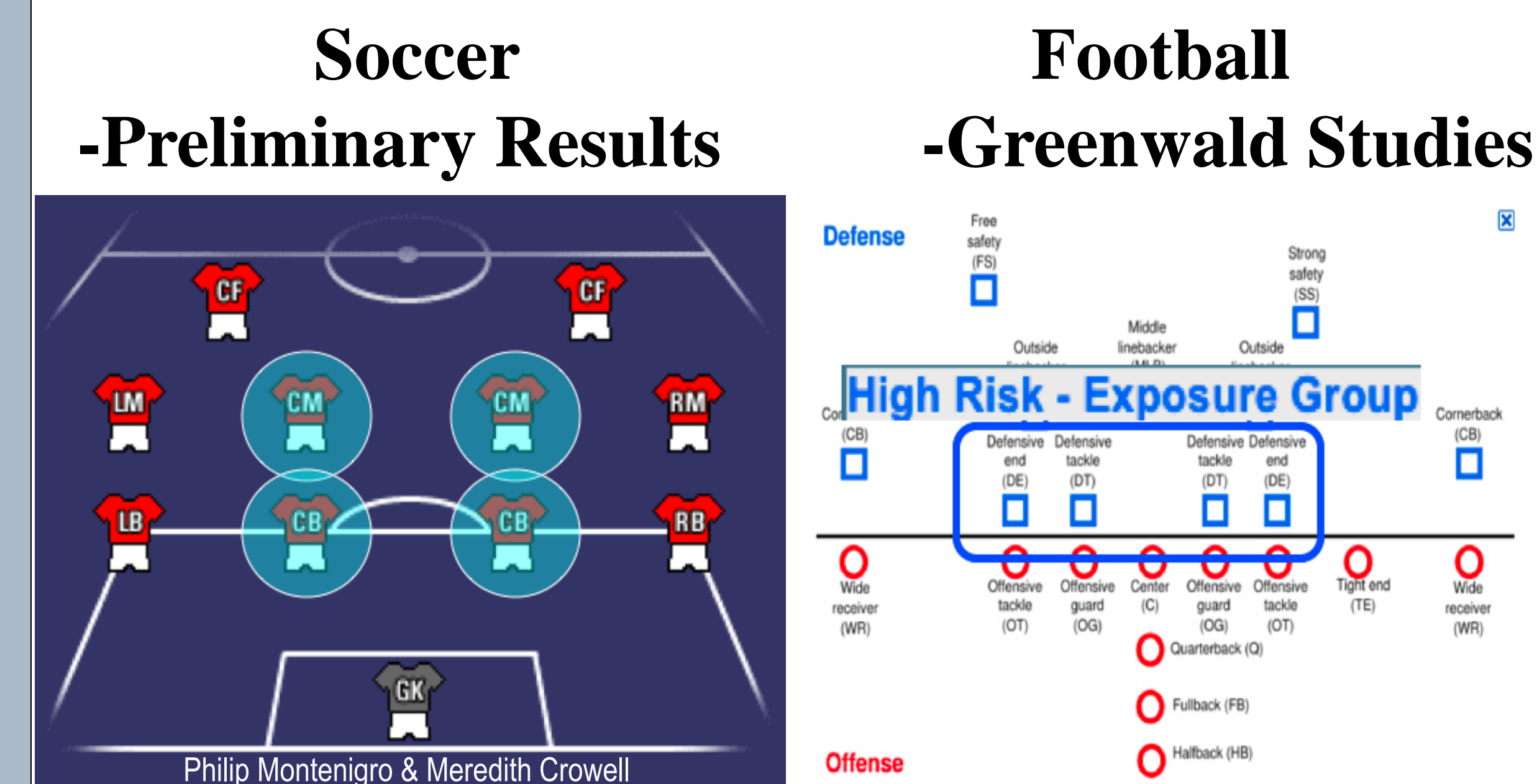
- A. Frontal Coup
  - B. Counter Coup of Midbrain
  - C. +/- Diffuse Axonal Injury & shear forces resultant of concussions
- [Diffusion Tensor Imaging]



### [Delayed Onset] CTE

- A. Frontal - Executive Dysfunction  
-Earliest symptoms of CTE
- B. Counter Coup of Midbrain  
-Cavum Septum, Widened Ventricles, Pallor of the Substantia Nigra, Cerebellar Scar
- C. Corpus Callosum Atrophy

## SOCCER COHORT STUDY



### High Risk Position :

- 1. Center > 850
- 2. + SC Trauma.
- 3. + Impact Profile

## CONCLUSIONS & FUTURE DIRECTIONS

•Subconcussive impacts above a certain threshold result in neurological trauma.

•Neurological sequelae of subconcussive trauma may be the earliest signs of CTE.

•The impact profiles vary according to sport however hits to the top of the head that are mild and cumulative are common among boxing, football and soccer and could be linked to the development of CTE via midbrain shear forces.

•Future studies determining exact hit counts are needed to develop an inter-sport threshold for subconcussive trauma.

