Long-term consequences of repetitive head impacts in adolescent athletes

Géraldine Martens, PT, PhD

GIGA Consciousness - ULiège

Type of sport ↔ type of risk

High risk	Moderate risk	Low risk
American Football	Cheerleading	Baseball
Ice Hockey	Volleyball	Softball
Soccer (F)	Soccer (M)	Gymnastic
Rugby	Cycling	Trampoline
Boxing	Basketball (M)	Swimming
Basketball (F)	Alpine Skiing	Equestrian sports
Lacrosse	Handball (M)	Golf
Wrestling	Skating	Athletics
Handball (F)	Diving	Badminton
Judo	Waterpolo	Biathlon/duathlon
Combat sports		Running
Kick-boxing		Cricket
MMA		CrossFit
Ringette		Dance
		…

Van Pelt et al., Sports Medicine 2021; Clay et al., Journal of chiropratic medicine 2013

Sport-related concussion vs. head impact exposure ?

High risk sports = contacts/impacts ++

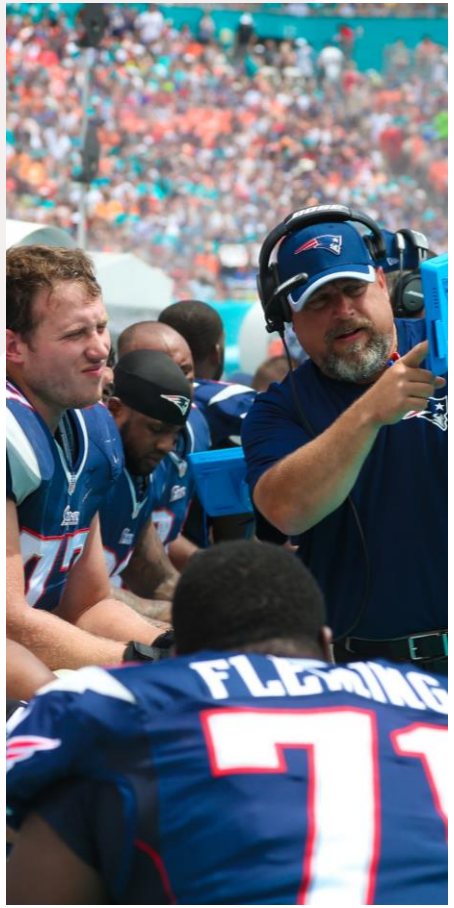
High risk of **concussive** (= diagnosed concussion) or **subconcussive** (= altered brain functioning without visible clinical signs) impacts

Affects short-term and long-term brain health (e.g., motor control and memory performance)

→ Monitoring head impact exposure (HIE)

Sport-related concussion: head impact exposure

Monitoring head impact exposure – accelerometry



Skin patch

Instrumented helmets

Instrumented mouthguards

Head impact exposure: acute effects

Example of altered brain functioning without clinically diagnosed concussion (= subconcussive impacts) :

head impact exposure (HIE) vs. brain excitability (intracortical inhibition M1)

JNS

CLINICAL ARTICLE

Short-term changes in the physiology of the primary motor cortex following head impact exposure during a Canadian football game

*Sophie-Andrée Vinet, MSc,[1,2] Géraldine Martens, PhD,[1,3] Samuel Guay, BA,[1,2] Amélie Apinis-Deshaies, PhD,[1] Johan Merbah, PhD,[1] Bertrand R. Caré, PhD,[1,4] Laurie-Ann Corbin-Berrigan, PhD,[5] Eric Wagnac, PhD,[1,6] and Louis De Beaumont, PhD[1,3]

[1]Montréal Sacred Heart Hospital Research Center, Montréal, Québec, Canada; [2]Psychology Department, University of Montréal, Québec, Canada; [3]Surgery Department, University of Montréal, Québec, Canada; [4]BERGIA Solutions, Toulon, Var, France; [5]Department of Physical Activity Sciences, University of Quebec at Trois-Rivières, Québec, Canada; and [6]Department of Mechanical Engineering, Superior Technology School, Montréal, Québec, Canada

* S.A.V. and G.M. contributed equally to this work.

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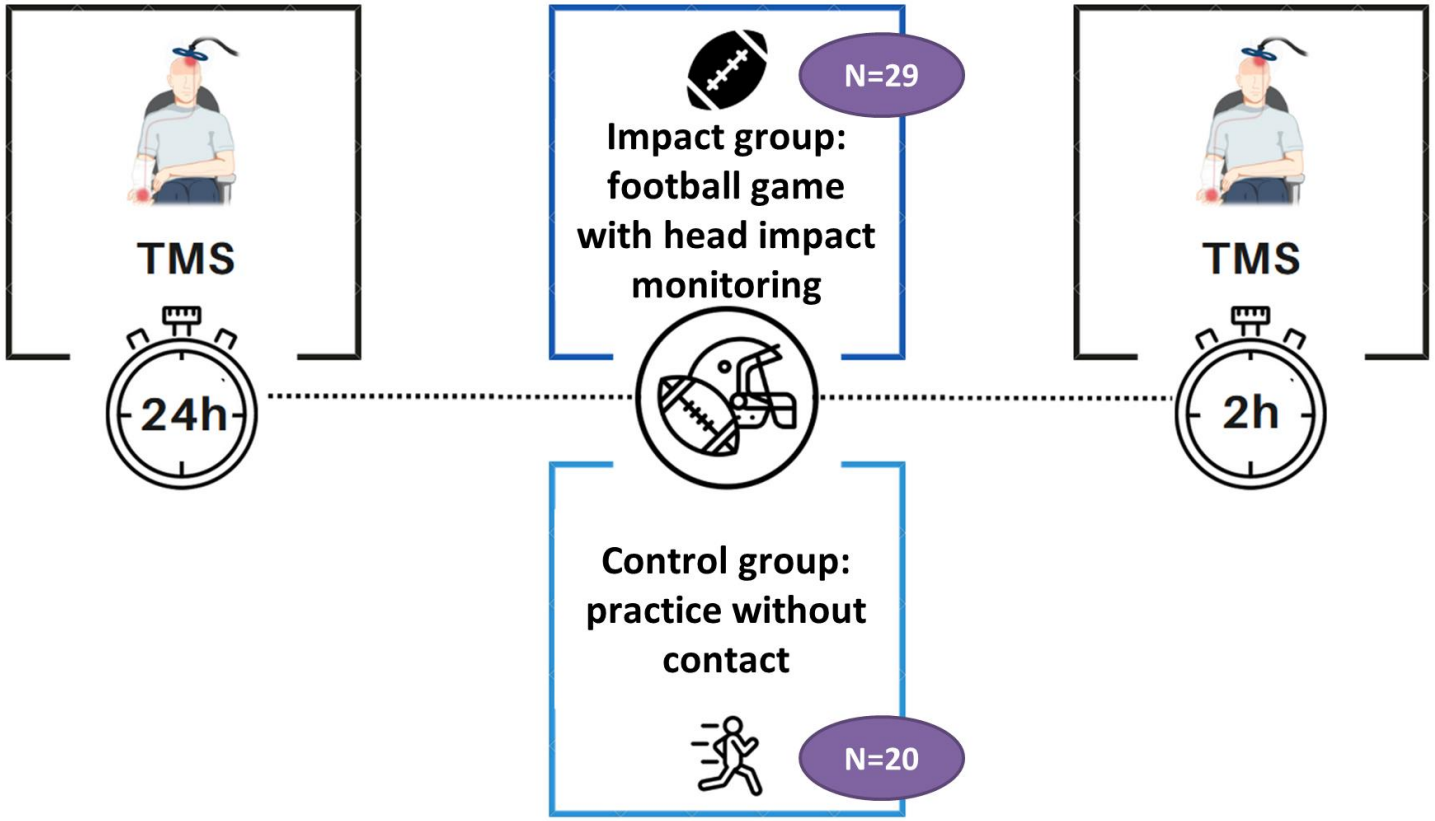
Head impact exposure: acute effects – transcranial magnetic stimulation (TMS)

Example of altered brain functioning without clinically diagnosed concussion (= subconcussive impacts) :

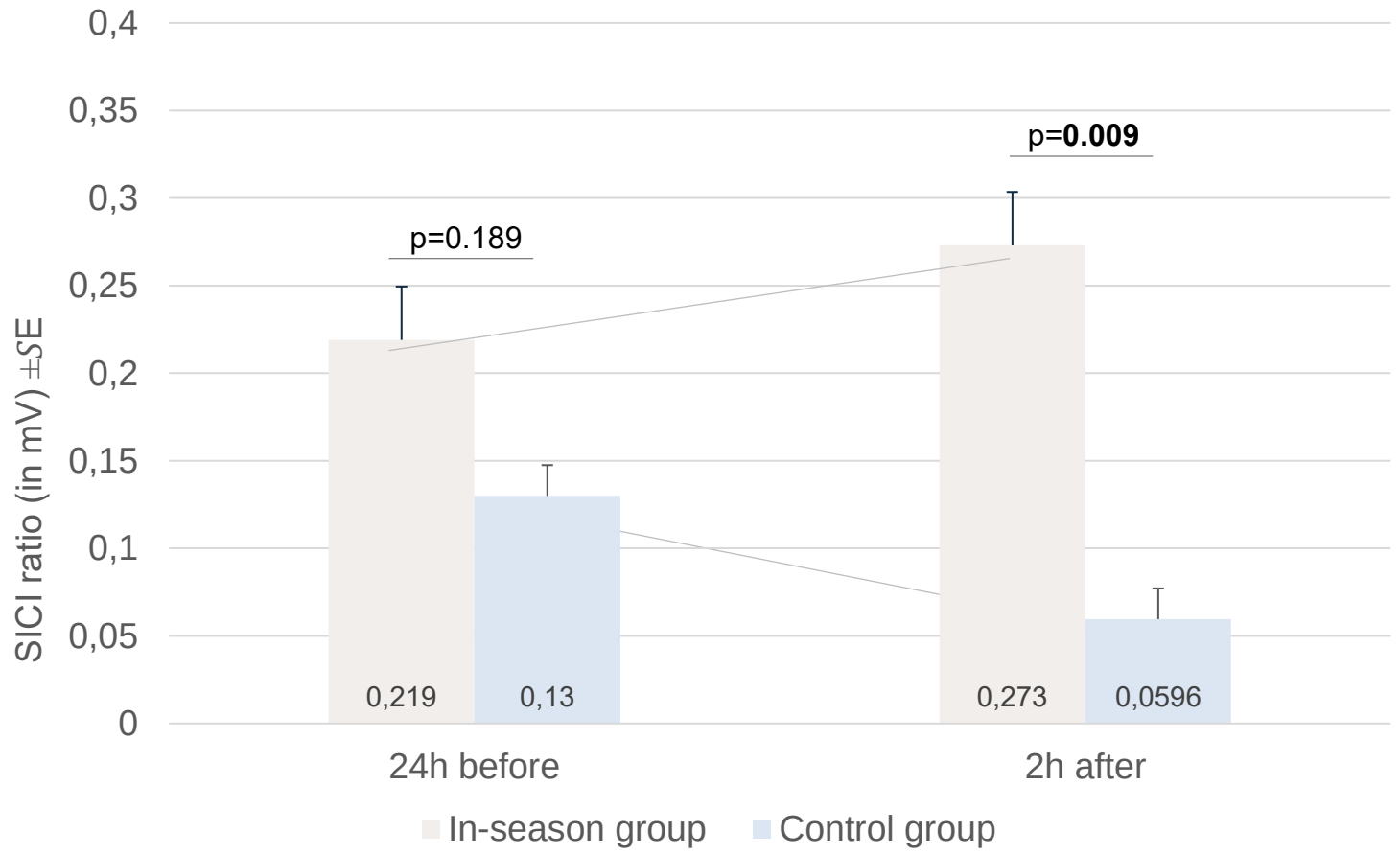
head impact exposure (HIE) vs. brain excitability (intracortical inhibition M1)

Male athletes
Varsity football
McGill & UdeM
2021-2022 seasons
Random assignment



Head impact exposure & TMS

Results: intracortical inhibition (TMS)



2x2 mixed ANOVA
Time * Group
$F(1, 44) = 5.19$
$p = 0.028$
$\eta^2 = 0.106$

Head impact exposure & TMS

Results: intracortical inhibition (TMS)

Changes observed over one game (acute)

Impacts over a season? – under investigation

Potential impacts over a whole career?

2x2 mixed ANOVA
Time * Group
$F(1, 44) = 5.19$
$p = 0.028$
$\eta^2 = 0.106$

National Football League (NFL) players survey

- About 40% of former players report significant difficulties with cognition & mental health

- > 1/3 of former NFL players report being ‘extremely concerned’ about cognition & CTE

BUT

- Modifiable factors associated with such impairments (depression, pain, sleep apnoea)

- High quality case-control & cohort studies needed

Plessow et al., J Neurotrauma 2020; Walton et al., Sports Med 2022; Roberts et al., J Neurotrauma 2021

Head impact exposure: chronic effects

British Journal of Sports Medicine

Systematic review

Examining later-in-life health risks associated with sport-related concussion and repetitive head impacts: a systematic review of case-control and cohort studies

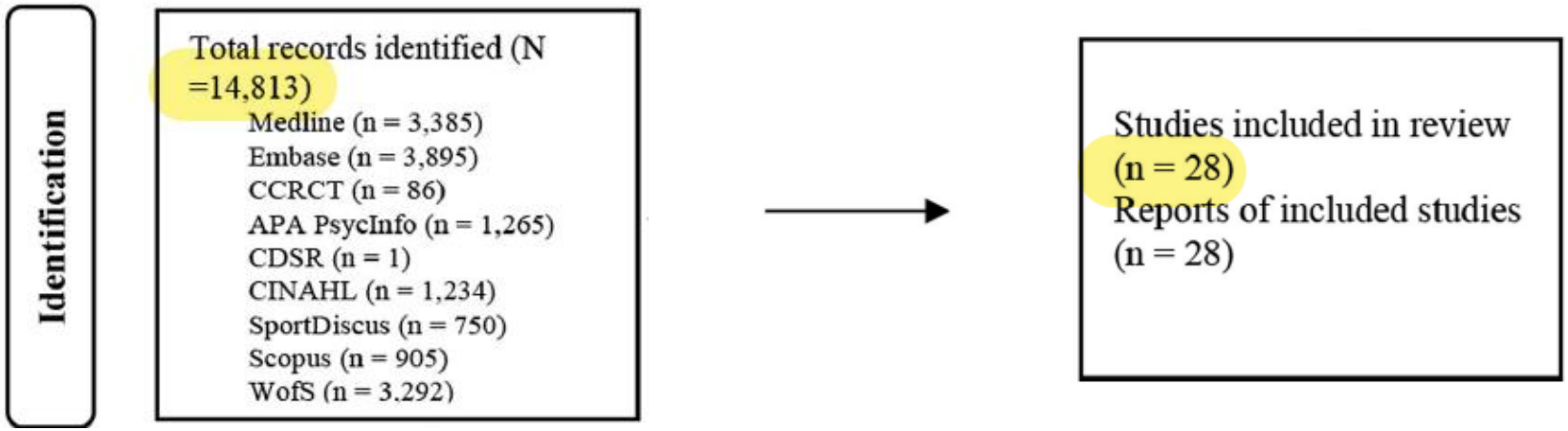
Grant L Iverson [1,2,3,4,5] Rudolph J Castellani,[6] J David Cassidy,[7] Geoff M Schneider,[8] Kathryn J Schneider [9] Ruben J Echemendia [10,11] Julian E Bailes,[12,13] K Alix Hayden,[14] Inga K Koerte [15,16,17] Geoffrey T Manley [18] Michael McNamee,[19,20] Jon S Patricios [21] Charles H Tator [22,23] Robert C Cantu,[24,25] Jiri Dvorak [26]

Head impact exposure: chronic effects

Brain health (cognitive impairment, mental health, neurological diseases…) in former athletes having sustained concussion and/or repetitive head impacts during youth sports?

1) What are the possible long-term effects of single and multiple sport-related concussions?

2) What are the possible long-term effects of exposure to contact sports and/or repetitive head impacts?



1 low-medium RoB
27 high RoB

Head impact exposure: chronic effects

Brain health (cognitive impairment, mental health, neurological diseases…) in former athletes having sustained concussion and/or repetitive head impacts during youth sports?

Results

Amateur athletes (10 studies, American football ++) → no significant long-term effect following sports participation
One exception: Decreased risk for depression (high school football)

Professional athletes (18 studies, American football, soccer) → **13 with greater risk** for developing depression, physical dysfunctioning, neurodegenerative disease (e.g., ALS, AD, PD) or all-cause mortality

Head impact exposure: chronic effects

9 studies on former professional American football players

Depression

ALS

All-cause mortality

Neuro-degenerative mortality

Table 3 Summary of findings from studies of former professional American football players

Study	Country	N	Group	Age	Exposure	Topic/Outcome	Significant findings/risk
Kerr *et al*[94]	USA	2001 cohort=3729 of which 2536 completed the survey; 1044 with complete data in 2010	Football (NFL)	NR	Concussions	Between 2001 and 2010, 10.2% reported a diagnosis of depression. Greater concussion history associated with greater risk for depression (eg, 3.0% in those with no prior concussions and 26.8% in those with 10+ prior concussions).	Yes/Greater
Brett *et al*[114]	USA	2001 cohort=3729 of which 2536 completed the survey; 333 had results in 2019	Football (NFL)	Age in 2001: M=48.95, SD=9.37; Approx. average age in 2019=67	Self-reported concussions and years of participation	Depression not greater than general population. Physical functioning rated worse than general population and decline in physical function associated with depression. Symptoms of depression associated with greater concussion history, but not years of participation.	Yes/Greater
Daneshvar *et al*[115]	USA	19 423; 38 ALS cases	Football (NFL)	Cohort range=23–78 ALS age of diagnosis M=51.0, SD=13.8	Sports participation	ALS more common in former NFL players than general population and associated with a longer career.	Yes/Greater
Kmush *et al*[116]	USA	14 366; 763 deaths	Football (NFL)	Age at death: M=53.3, SD=14.6	Repetitive head impacts derived from playing position and career duration	Repetitive head impacts (ie, player position) associated with greater all-cause mortality.	Yes/Greater
Nguyen *et al*[117]	USA	NFL=3419, 517 deaths; MLB=2708, 431 deaths	Football (NFL)	Age at death: NFL M=59.6, SD=13.2; MLB M=66.7, SD=12.3	Sports participation	Former NFL players had greater neurodegenerative disease mortality (7.5% of former NFL players (39/517) and 3.7% of former MLB players (16/431). Suicide was not significantly greater in former NFL players (11/517; 2.1%) compared with former MLB players (5/431; 1.2%).	Yes/Greater
Baron *et al*[126]	USA	3439, 334 deaths	Football (NFL)	At death: Md=54, Range=27–81	Sports participation	Lower risk of mortality from mental disorders and suicide in former NFL players compared with men in the general population. No difference in diseases of the nervous system and sense organs.	No Yes/Lesser
Lincoln *et al*[127]	USA	9778; 227 deaths	Football (NFL)	At death: Md=38, Range=23–61	Sports participation	Lower risk of mortality from mental disorders and suicide in retired NFL players; No difference in diseases of the nervous system and sense organs.	No Yes/Lesser
Lehman *et al*[118]	USA	3439; 537 deaths	Football (NFL)	NR	Sports participation	Former NFL players less likely to have suicide as manner of death than men from the general population.	Yes/Lesser
Lehman *et al*[119]	USA	3439; 334 deaths	Football (NFL)	Md=54 at death	Sports participation	Neurodegenerative disease mortality (17/334 deaths, 5.1%), primarily dementia and ALS, greater in former NFL players than the general population.	Yes/Greater

ALS, amyotrophic lateral sclerosis; M, mean; MCI, mild cognitive impairment; Md, median; MLB, Major League Baseball; NA, not available; NFL, National Football League; NR, not reported.

Head impact exposure: chronic effects

8 studies on former professional European soccer players

Table 4 Summary of findings from studies of former elite and professional athletes from Europe and Australia

Study	Country	N	Group	Age	Exposure	Topic/Outcome	Significant Findings/ risk
Taioli[128]	Italy	5389; 63 had died	Soccer	At death: 36.3 (10.3)	Sports participation	No significant difference in risk for suicide as manner of death than general population. Greater risk for ALS.	No for suicide Yes, greater for ALS
Russell *et al*[122]	Scotland	Soccer=7676 Controls=23 028	Scottish Soccer	At first hospitalisation: soccer: M=52.3, SD=13.6; controls: M=46.8, SD=14.7	Sports participation	Hospitalisation for psychiatric and substance abuse problems *less* common in former soccer players. No difference in suicide.	Yes, lesser for psychiatric and substance abuse No for suicide
Belli *et al*[129]	Italy	24 000; 350 had died	Italian Soccer	At death: M=50.8, SD=15.2	Sports participation	ALS more common in former soccer players; other disease of the nervous system not more common.	Yes, greater for ALS No for other diseases
Pupillo *et al*[130]	Italy	23 586; 34 cases of ALS	Italian Soccer	M=45.0, SD=12.6 at diagnosis	Sports participation	ALS more common in former Italian soccer players.	Yes/Greater
Chio *et al*[132]	Italy	7325; 5 cases of ALS	Italian Soccer	Age of onset M=43.4 (SD=9.1; range 33–56)	Sports participation	ALS more common in former Italian soccer players.	Yes/Greater
Chio *et al*[133]	Italy	7325; 5 cases of ALS	Italian Soccer	Age of onset M=41.6 years (SD=7.5, range 33–56 years).	Sports participation	ALS more common in former Italian soccer players.	Yes/Greater
Russell *et al*[120]	Scotland	Soccer=7676; controls=23 028	Scottish Soccer	NR	Sports participation	Neurodegenerative disease mortality greater in former soccer players, varied by position played and increased with career length.	Yes/Greater
Mackay *et al*[124]	Scotland	Soccer=7676, 1180 deaths; controls=23 028, 3807 deaths	Scottish Soccer	At death: soccer M=67.9, SD=13.0; controls M=64.7, SD=14.0	Sports participation	Neurodegenerative disease mortality greater in former soccer players (eg, AD, ALS and PD).	Yes/Greater

The two studies by Chio *et al* used the same cohort of players,[132 133] and the three studies with former Scottish players used the same cohort.[120 122 124] Many of these studies are ecological analyses with positive associations being important hypothesis-generating findings; more meticulously designed cohort studies with better control for confounding factors are needed.

AD, Alzheimer's disease; ALS, amyotrophic lateral sclerosis; M, mean; NR, not reported; PD, Parkinson's disease.

ALS

Neuro-degenerative mortality

The problem

Results can seem unequivocal at first glance **but**

No control for confounding variables:
- Substance abuse (drugs, alcohol, smoking)
- Socioeconomic status
- Genetic factors
- Lifestyle
- Medical comorbidities

➔ Most of the retrieved studies are hypothesis generating but do not allow causal conclusions

Chronic traumatic encephalopathy (CTE)

Chronic traumatic encephalopathy (CTE) = neuropathological entity (p-tau aggregates in neurons) → **postmortem** (not included in SR)

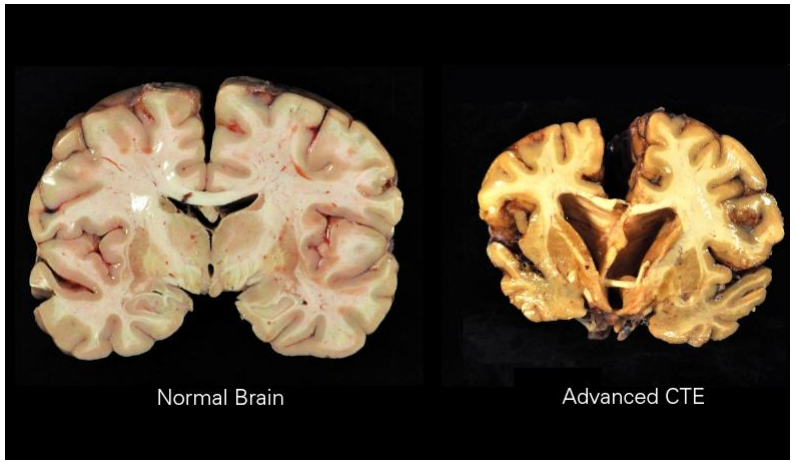
Highly prevalent (with high variability) if former professional American football athletes

No clinical phenotype determined

Consensus-based clinical criteria (2021) for traumatic encephalopathy syndrome (TES):

- History of substantial exposure to repetitive head impacts
- Cognitive impairment
- Behavioural dysregulation
- Progressive course

Criteria remain to be validated



Katz et al., Neurology 2021

Controversies arising from preliminary studies

Cross-sectional studies, case series, narrative reviews…

The Guardian

Analysis

A new consensus? Change in the air as concussion conference begins

Andy Bull

Much is at stake as the sixth International Consensus Conference on Concussion in Sport gets under way in Amsterdam

The New York Times

Scientists Say Concussions Can Cause a Brain Disease. These Doctors Disagree.

THE CONVERSATION

Do repetitive head injuries really cause the degenerative brain disease CTE? New research questions the link

Controversies arising from preliminary studies

Cross-sectional studies, case series, narrative reviews…

- Hypotheses for future cohort and case-control studies
- No causation
- Drew lot of attention and visibility (including press)
- Mixed messages for the general public

➔ **Urgent need for well-designed case-control and cohort studies**


The New York Times

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To conclude

Crude associations between history of professional contact and collision sports and some neurological disorders

These associations need to be confirmed in more rigorous study designs

Youth sports: let’s be conservative & act on prevention + education

Adult amateur/leisure sports: you’re *probably* fine

Thank you for your attention!

geraldine.martens@uliege.be