



## Risk of chronic traumatic encephalopathy in rugby union is associated with length of playing career

William Stewart<sup>1,2</sup> · Michael E. Buckland<sup>3,4</sup> · Bobak Abdolmohammadi<sup>5</sup> · Andrew J. Affleck<sup>3,4</sup> · Victor E. Alvarez<sup>5,6,7,8</sup> · Shannon Gilchrist<sup>1</sup> · Bertrand R. Huber<sup>5,6,7,9,10</sup> · Edward B. Lee<sup>11</sup> · Donald M. Lyall<sup>12</sup> · Christopher J. Nowinski<sup>5,13</sup> · Emma R. Russell<sup>1</sup> · Thor D. Stein<sup>5,6,8,9</sup> · Catherine M. Suter<sup>3,4</sup> · Ann C. McKee<sup>5,6,7,8,9,10,14</sup>

Received: 19 September 2023 / Revised: 4 October 2023 / Accepted: 4 October 2023 / Published online: 24 October 2023  
© The Author(s) 2023

There is concern over late, adverse brain health outcomes associated with contact sports participation, with high neurodegenerative disease risk reported in studies of former American football [3, 8], soccer [9, 16] and rugby union players [15]. In parallel, autopsy studies of former athletes from a range of contact sports describe a frequent finding of chronic traumatic encephalopathy (CTE), a neuropathology uniquely associated with prior history of traumatic brain injury (TBI) and repetitive head impact (RHI) exposure [7, 12–14]. Among contact sports, rugby union (hereafter ‘rugby’) is documented as having high risk of concussion/mild TBI, with reported injury rates ranging 4.1 concussions/1000 player hours at community level [2] to 22.2 concussions/1000 player hours in professional rugby [4]. Nevertheless, despite its popularity, with a reported 8.46 million active participants globally [20], there have been relatively few case descriptions of CTE in former rugby players [7, 17, 18]. To address this, we collated and analyzed

neuropathological data from autopsy brain examinations on individuals with rugby as primary sport exposure submitted to three international brain banks with specific interest in contact sport and brain health.

Case records of the Understanding Neurologic Injury and Traumatic Encephalopathy Brain Bank (UNITE; Boston University School of Medicine, US), the Glasgow TBI Archive (GTBI; University of Glasgow, UK) and the Australian Sports Brain Bank (ASBB; Royal Prince Alfred Hospital and University of Sydney, Australia) were surveyed to identify case donations in which primary sport exposure was recorded as ‘rugby union’. Each archive employs standardized procedures for case accrual, clinical history acquisition and tissue processing, with neuropathological evaluations conducted blind to demographic and clinical information and employing established, consensus protocols for assessment of neurodegenerative disease pathologies, including CTE [1, 11, 13]. For the purposes of this study, existing

✉ William Stewart  
william.stewart@glasgow.ac.uk

<sup>1</sup> School of Psychology and Neuroscience, University of Glasgow, Glasgow G12 8QQ, UK

<sup>2</sup> Department of Neuropathology, Queen Elizabeth University Hospital, 1345 Govan Rd, Glasgow G51 4TF, UK

<sup>3</sup> Department of Neuropathology, Royal Prince Alfred Hospital, Camperdown, NSW, Australia

<sup>4</sup> School of Medical Sciences, University of Sydney, Camperdown, NSW, Australia

<sup>5</sup> Alzheimer’s Disease Research Center and Chronic Traumatic Encephalopathy Center, Chobanian and Avedisian School of Medicine, Boston University, Boston, MA 02118, USA

<sup>6</sup> US Department of Veteran Affairs, Veterans Affairs (VA) Boston Healthcare System, Boston, MA 02130, USA

<sup>7</sup> Department of Neurology, Chobanian and Avedisian School of Medicine, Boston University, Boston, MA 02118, USA

<sup>8</sup> Department of Pathology and Laboratory Medicine, Chobanian and Avedisian School of Medicine, Boston University, Boston, MA 02118, USA

<sup>9</sup> US Department of Veteran Affairs, VA Bedford Healthcare System, Bedford, MA 01730, USA

<sup>10</sup> National Center for PTSD, VA Boston Healthcare, Boston, MA 02130, USA

<sup>11</sup> Translational Neuropathology Research Laboratory, University of Pennsylvania, Philadelphia, PA 19104, USA

<sup>12</sup> School of Health and Wellbeing, University of Glasgow, Glasgow G12 8QQ, UK

<sup>13</sup> Concussion Legacy Foundation, Boston, MA 02115, USA

<sup>14</sup> Department of Biostatistics, Boston University School of Public Health, Boston, MA 02118, USA

archive datasets were interrogated to extract relevant demographic information (age at death, sex), sports exposure history (years duration of rugby participation, position played [dichotomized as forward or back], highest level of participation [dichotomized as amateur or elite (encompassing representative international and/or professional)], other contact sport exposure) and principal neuropathological findings.

In total, 31 cases where primary sports exposure was documented as rugby union were identified within contributing research brain banks: 16 cases from UNITE; 8 from GTBI; and 7 from ASBB. Among these, mean age at death was 60.4 years (standard deviation [SD] 21.7 years; range 17–95 years), with all but 1 (3%) case male. Reported rugby career length averaged 18.3 years (SD 10.0 years; range 2–35 years), with an equal number of forward and backs, where information on player field position was available. Twenty-three (74%) played rugby exclusively as amateurs, with 8 (26%) reaching elite (representative/ professional) level and 19 of 29 (66%) reporting history of prior TBI with loss of consciousness and/or history of concussion.

Regarding neuropathological findings, CTE was present in 21 of 31 (68%) brains of former rugby players examined, a majority of whom (13/21; 62%) played solely at amateur level. Among cases with CTE, 14 were typical of low-stage CTE pathology, 7 high stage [1]. No notable differences were observed between players with or without CTE in respect of age at death, participation in other contact sports, history of drug or alcohol use disorder, whole brain weight at autopsy, prevalence of septum pellucidum abnormalities (Table 1) or wider neuropathologies assessed (Supplementary Table 1). However, players with CTE typically had longer rugby playing careers than those without CTE. Indeed, adjusted for age at death, a dose–response relationship was evident between career length and the presence of CTE at autopsy, with each additional year of play associated with an approximately 14% increase in CTE risk (relative risk ratio 1.138; 95% confidence interval 1.015–1.277;  $P=0.027$ ; multinomial logistic regression). While history of TBI with loss of consciousness and/or concussion was common among cases with CTE, this was not significantly different to prevalence among cases without CTE.

An acknowledged limitation of this study is that our case series represents a convenience sample of brains donated for

research evaluation. Nevertheless, our observation that CTE pathology is present in around two-thirds of former rugby union players examined is in line with experience reporting neuropathological findings in other series of former contact sports athletes, including former American footballers and soccer players [7, 13]. Notably, a majority of our cases played solely at amateur level, including those with CTE. First played in the nineteenth century, rugby remained an amateur sport until 1995 when professionalism was permitted. With an average age among our cohort around 60 years, it is perhaps not surprising that the majority are defined as amateur. Intriguingly, some observers suggest that contact sport-related late adverse brain health outcomes might be restricted solely to professional athletes [5]. In respect of CTE, at least, our data suggest that level of participation does not protect against development of this neurodegenerative pathology.

In contrast, among this case series, there was clear association between length of rugby playing career and risk of CTE, which was independent of age at death. Again, this is in line with observations among several contact sports demonstrating longer playing careers associated with increased risk of a neurodegenerative disease diagnosis [3, 16] and, independently, with increased risk of CTE pathology [6, 10]. These data would be consistent with risk resulting from cumulative exposure to a factor associated with sport. To date, the only recognized risk factor for development of CTE is TBI and/or RHI exposure. Rugby union is recognized as having a notably high risk of concussion compared to wider contact sports [19], with risk at professional level increasing over the past 20 years [4].

In summary, in this convenience sample of research brain donations from former rugby union players, we found clear evidence of CTE pathology in around two-thirds of cases. Further, risk of CTE was directly associated with length of rugby playing career, interpreted as a surrogate for head impact exposure. These data reinforce concern around adverse brain health outcomes among former contact sports athletes and add to evidence in support of calls to reduce exposure to repetitive head impacts and risk of traumatic brain injury in training and in match play across all sports.

**Table 1** Demographic and primary neuropathological findings

	CTE N=21	No CTE N=10	P
Demographic information			
Mean age at death (standard deviation) [range]	61.7 years (17.5)[23–94]	57.8 years (29.7)[17–95]	0.710*
Sex			NA
Male	21	9	
Female	0	1	
Years rugby participation (standard deviation) [range]	21.5 years (8.1)[8–35]	12.1 years (10.9)[2–15]	0.031*
Position			NA
Unknown	7	8	
Forward	7	1	
Back	7	1	
Highest participation level			NA
Amateur	13	10	
Elite	8	0	
Other contact sports			1.000**
None	12	6	
American football	5	2	
Boxing	3	0	
Soccer	2	1	
Ice Hockey	2	0	
Rugby league	1	0	
Wrestling	0	1	
TBI with LOC and/or concussion			0.083**
Unknown	0	2	
None	5	5	
Yes	16	3	
Alcohol use disorder			1.000**
Unknown	5	4	
No	9	4	
Yes	7	2	
Drug use disorder			0.120**
Unknown	6	4	
No	12	2	
Yes	3	4	
Neuropathology findings			
Mean brain weight (standard deviation)[range]	1353 g (208 g)[1030–1680 g]	1321 g (186 g) [1060–1449 g]	0.677*
Septum pellucidum			0.422**
Not available	1	1	
Intact	7	5	
Cavum/fenestrated	13	4	
CTE			NA
None	0	10	
Low stage	14	0	
High stage	7	0	

CTE chronic traumatic encephalopathy, LOC loss of consciousness, NA not assessed as data insufficient and/or inappropriate for analysis, TBI traumatic brain injury. \*Student's *t* test. \*\*Fisher's exact with data dichotomized as feature present versus absent

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s00401-023-02644-3>.

**Acknowledgements** This work is supported by funding from: the National Institute of Neurological Disorders and Stroke of the National Institutes of Health (Award Nos. R01NS092398, R01NS094003, R01NS038104, U54NS115322, U01NS086659, U01NS093334, U54NS115266, R01NS078337, and R56NS078337); National Institute on Aging (Award Nos. AG057902, AG06348 and supplement 0572063345); US Department of Veterans Affairs (CX00135 to Dr. McKee and CX001038 to Dr. Stein); The Concussion Legacy Foundation; The Andlinger Foundation; and an NHS Research Scotland Career Researcher Fellowship (WS). The ASBB is supported by Sydney Local Health District and unrestricted philanthropic donations.

**Author contributions** WS, EBL, AJA, CMS, ACM, TS, BRH, VA, and MEB conducted the original pathology assessments, collated clinical data, and generated the original observations at each site; DML, EM, and WS analyzed the collated datasets; WS provided a first draft of the manuscript and collated comments into a final submission draft; all other authors provided edits and comments on manuscript drafts.

**Data availability** The datasets supporting the conclusions of this article are available from participating archives on application.

## Declarations

**Conflict of interest** The authors declare no competing interests.

**Ethics approval** The Glasgow TBI Archive has specific Research Ethics Committee approval as a Research Tissue Bank (ref 22/WS/0168). The Australian Sports Brain Bank has ethical approval granted by the Sydney Local Health District Human Research Ethics Committee, Royal Prince Alfred Hospital (ref: X23-0073).

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

## References

1. Bieniek KF, Cairns NJ, Crary JF et al (2021) The second NINDS/NIBIB consensus meeting to define neuropathological criteria for the diagnosis of chronic traumatic encephalopathy. *J Neuropathol Exp Neurol* 80:210–219
2. Community Rugby Injury Surveillance Project Steering Group. Community Rugby Injury Surveillance and Prevention Project Men's 1st team injuries across playing levels 3–9 in England: Season Report 2019–2020. <https://keepyourbootson.co.uk/wp-content/uploads/2022/03/CRISP-2019-20.pdf>. Accessed 19th Sept 2023
3. Daneshvar DH, Mez J, Alosco ML et al (2021) Incidence of and mortality from amyotrophic lateral sclerosis in National Football League athletes. *JAMA Netw Open* 4:e2138801
4. England Professional Rugby Injury Surveillance Project Steering Group. England professional rugby injury surveillance project:

Season report 2020–2021. <https://keepyourbootson.co.uk/wp-content/uploads/2023/01/PRISP-2020-21.pdf>. Accessed 13th Sept 2023

5. Iverson GL, Castellani RJ, Cassidy JD et al (2023) Examining later-in-life health risks associated with sport-related concussion and repetitive head impacts: a systematic review of case-control and cohort studies. *Br J Sports Med* 57:810–821
6. LeClair J, Weuve J, Fox MP et al (2022) Relationship between level of american football playing and diagnosis of chronic traumatic encephalopathy in a selection bias analysis. *Am J Epidemiol* 191:1429–1443
7. Lee EB, Kinch K, Johnson VE, Trojanowski JQ, Smith DH, Stewart W (2019) Chronic traumatic encephalopathy is a common comorbidity, but less frequent primary dementia in former soccer and rugby players. *Acta Neuropathol* 138:389–399
8. Lehman EJ, Hein MJ, Baron SL et al (2012) Neurodegenerative causes of death among retired National Football League players. *Neurology* 79:1970–1974
9. Mackay DF, Russell ER, Stewart K et al (2019) Neurodegenerative disease mortality among former professional soccer players. *N Engl J Med* 381:1801–1808
10. Mez J, Daneshvar DH, Abdolmohammadi B et al (2020) Duration of American football play and chronic traumatic encephalopathy. *Ann Neurol* 87:116–131
11. McKee AC, Cairns NJ, Dickson DW et al (2016) The first NINDS/NIBIB consensus meeting to define neuropathological criteria for the diagnosis of chronic traumatic encephalopathy. *Acta Neuropathol* 131:75–86
12. McKee AC, Mez J, Abdolmohammadi B, et al (2023). Neuro-pathologic and Clinical Findings in Young Contact Sport Athletes Exposed to Repetitive Head Impacts [published online ahead of print, 2023 Aug 28]. *JAMA Neurol* e232907. <https://doi.org/10.1001/jamaneurol.2023.2907>
13. McKee AC, Stein TD, Huber BR et al (2023) Chronic traumatic encephalopathy (CTE): criteria for neuropathological diagnosis and relationship to repetitive head impacts. *Acta Neuropathol* 145:371–394
14. McKee AC, Stern RA, Nowinski CJ et al (2013) The spectrum of disease in chronic traumatic encephalopathy. *Brain* 136:43–64
15. Russell ER, Mackay DF, Lyall D, Stewart K, MacLean JA, Robson J et al (2022) Neurodegenerative disease risk among former international rugby union players. *J Neurol Neurosurg Psychiatry* 93:1262–1268
16. Russell ER, Mackay DF, Stewart K et al (2021) Association of field position and career length with risk of neurodegenerative disease in male former professional soccer players. *JAMA Neurol* 78:1057–1063
17. Stewart W, McNamara PH, Lawlor B, Hutchinson S, Farrell M (2016) Chronic traumatic encephalopathy: a potential late and under recognized consequence of rugby union? *QJM* 109:11–15
18. Suter CM, Affleck AJ, Lee M, Pearce AJ, Iles LE, Buckland ME (2022) Chronic traumatic encephalopathy in Australia: the first three years of the Australian Sports Brain Bank. *Med J Aust* 216:530–531
19. Van Pelt KL, Puetz T, Swallow J, Lapointe AP, Broglio SP (2021) Data-driven risk classification of concussion rates: a systematic review and meta-analysis. *Sports Med* 51:1227–1244
20. World Rugby. Global rugby participation increasing ahead of Rugby World Cup 2023 <https://www.rugbyworldcup.com/2023/news/836825/global-rugby-participation-increasing-ahead-of-rugby-world-cup-2023> Accessed 15th Sept 2023

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.