Written evidence submitted by Dr Karen Hind of the Department of Sport and Exercise Sciences, Durham University.

1) Unpublished findings from the UK Rugby Health project.

Dr Karen Hind, Mr Ian Entwistle, Miss Natalie Konerth, Dr Paul Chazot, Mr Thomas Goodbourn, Miss Marianna Bottiglieri, Miss Paula Ferraces-Reigas, and Professor Amanda Ellison from Durham University; Professor Patria Hume, Professor Alice Theadom, and Associate Professor Gwyn Lewis from Auckland University of Technology; Dr Doug King from the University of New England and AUT.

2) Note on blood biomarker research (UK Rugby Health project)

Dr Karen Hind, Dr Paul Chazot, Professor Melinda Fitgerald (Curtin University), and Professor Patria Hume.

3) Head impacts sustained by rugby union players in the current English Premiership.

Dr Karen Hind, Mr Thomas Goodbourn, and Mr Jonathan Frawley (Advanced Research Computing, Durham University).

4) Comment on research funding.

Dr Karen Hind, Professor Patria Hume and Dr Doug King on behalf of the Global Rugby Health Research Network.

1) Mental health and wellbeing, and associations with concussion in retired rugby players: the UK Rugby Health project

The manuscript is currently in peer review with Sports Medicine.

The UK Rugby Health project (launched in September 2016 and led by Dr Karen Hind) is part of the Global Rugby Health Research Network (founded and led by Prof Patria Hume, Dr Karen Hind and Dr Doug King) following the New Zealand Rugby Health project (led by Professor Patria Hume, Auckland University of Technology; funded in part by WR and NZ RFU). The study design and tools were adapted to the UK, included additional clinical measures and the study is independent of the sport governing bodies. The research was made possible through equipment loans, a small amount of internal funding (Durham University £4,500 and AUT $15,000) and involves a self-funded, part-time PhD student.

Research from the same project, on cumulative injuries across a rugby players' career, was published last year. Concussion was the most frequently reported injury for elite and amateur rugby players, and presented with the highest recurrence. Given the high number of reported concussions (and their recurrence) and associations between previous injuries during a player's career and current musculoskeletal conditions, we call for strategies and interventions to be put in place to support the specific physical health needs of rugby code athletes post-retirement.

Hind, K., Konerth, N., Entwistle, I., Theadom, A., Lewis, G., King, D., Chazot, P. and Hume, P., 2020. Cumulative sport-related injuries and longer term impact in retired male elite-and amateur-level rugby code athletes and non-contact athletes. Sports Medicine, 50:11.

Findings

The study sample included 189 retired elite (n=83) and amateur (n=106) rugby players and 65 retired non-contact athletes. Data were compared between groups and between exposure of three or more (≥3) or five or more (≥5) concussions.

- Retired elite rugby players reported more concussions across their playing career (5.9 ± 6.3) than retired amateur players (3.7 ± 6.3, $p = 0.022$) and non-contact athletes (0.4 ± 1.0, $p < 0.001$).
- Retired elite rugby players had a higher overall negative mental health score (indicating poor mental health) than retired amateur players ($p = 0.003$) and non contact athletes ($p = 0.006$).
- Retired elite rugby players had a lower overall positive score (indicating good mental health) than retired non contact athletes ($p = 0.021$).
- Negative scores were highest and positive scores lowest in those reporting ≥3 concussions ($p = 0.008$; $p = 0.040$ respectively) or ≥5 concussions ($p < 0.001$; $p = 0.035$ respectively).
- Reported symptoms for sleep disruption were more prevalent in retired elite rugby players than non contact athletes, and in former athletes with ≥3 concussions ($p < 0.010$).
- There were no significant differences in alcohol score.
- Global anger score and covert anger expression were higher in former athletes with ≥5 concussions ($p = 0.035$; $p = 0.016$).
- 20% of retired elite rugby players reported that they would not turn to anyone if they had a problem or felt upset about anything.

Considerations

First, as with similar studies involving the recruitment of volunteers, the study was subject to non-response or selection bias. Therefore, results may not be entirely generalisable to all rugby players, although the inclusion of both elite and amateur level former rugby code players increases the applicability of the study findings. Second, the cross-sectional design did not enable us to make causal inferences and longitudinal study designs that provide higher quality evidence of relationships between variables are warranted. There are experimental and imaging studies that have demonstrated associations between concussion, structural and functional brain alterations, sleep disruption and psychological symptomology. Third, although an unavoidable limitation of this research was retrospective reporting of concussions, moderate reliability has been demonstrated for the retrospective reporting of concussions by NFL players over a time gap of nine years (Kerr et al., 2012).

Summary

Psychological signs of more adverse mental health, and sleep disruption, were consistently more prevalent in retired elite rugby players and in former athletes who reported a higher number of concussions. Anger and irritability were more prevalent in former athletes with a history of ≥5 concussions. These findings provide evidence to support strategies to address mental health and sleep disturbance in elite rugby code athletes, who are also less likely to seek help should they need it. There is a need for research to elucidate the neurobiological connection between concussion and longer term psychological health and wellbeing.

Researchers: Dr Karen Hind, Mr Ian Entwistle, Miss Natalie Konerth, Dr Paul Chazot, Mr Thomas Goodbourn, Miss Marianna Bottiglieri, Miss Paula Ferraces-Reigas, and Professor Amanda Ellison from Durham University; Professor Patria Hume, Professor Alice Theadom, and Associate Professor Gwyn Lewis from Auckland University of Technology; Dr Doug King from the University of New England and AUT.

2) Note on blood biomarker research

We collected fasted blood serum and plasma samples from retired rugby players and non-contact athletes/controls between 2016 and 2018, as part of the UK Rugby Health project. Preliminary analysis of the serum samples has indicated a new and potential valuable lead for advancing understanding of the trajectory of neurodegenerative processes. This requires timely exploration, but is funding dependent. We also need to secure funding for the miRNA analyses. The level of funding required is in the region of £80,000. It is important to note that we also have a bank of contextual data such as sports participation, injury history, disease status, and neurocognition, to analyse together with the blood results.

Researchers: Dr Karen Hind (Durham University), Dr Paul Chazot (Department of Biosciences, Durham University), Professor Melinda Fitzgerald (Curtin University, Australia) and Professor Patria Hume (Auckland University of Technology, NZ).

3) Head Impacts in English Premiership Rugby Union

The research is a multi-modal evaluation of head impacts in professional rugby union players (head impacts, video analysis, blood markers, King Devick screening). We are measuring head impacts using Protxx sensors which are worn behind the ear. The study includes one professional rugby union club, with data collected from home matches and contact training sessions during the 2019-2020 Championship season, and the 2020-21 Premiership season. The research has received no external funding and involves a self-funded, full-time PhD student.

Sample findings

This data has been taken from a sample of two Premiership/European rugby union matches and two contact training days (two sessions on each day) during the current (2020-2021) season. The summary includes 47 players, although some players feature multiple times within the selected sample recording sessions. Players were divided into the following groups:

Table 1. *Player position groups*

Player Group	Player Positions
Group 1	Tighthead Prop, Hooker & Loosehead Prop
Group 2	Second Row
Group 3	Blindside Flanker, Openside Flanker & Number 8
Group 4	Scrum Half & Fly Half
Group 5	Inside Centre & Outside Centre
Group 6	Wing & Fullback

In the event of an individual playing different positions across multiple groups, if it was during a match, they were assigned to the group for the position that they were playing. However, during a training session the player would be assigned to the group for the position that they played most often. For example:

> *'TG25 usually plays in the second row, therefore, in training sessions he will always be listed in PG2, however, on occasion, TG25 plays in the back row for some matches and so will be listed as PG3 when that occurs.'*

Although there is not a numerically equal representation of all player groups in this snapshot, the data is representative of the traditional distribution of players across player groups, usually seen in a matchday squad.

Impact data is separated into two main metrics: linear force (g) and angular force (rads/s^2). In line with previous research (King et al., 2015), the minimum thresholds of 10g and 4600 rads/s^2 have been applied to filter out impacts considered to be negligible in causing subconcussive or concussive impact. Over 7,500 impacts registered over these thresholds in the two matches and a further 4,000 over threshold impacts were recorded on the two training days.

General Summary

Table 2. *Mean impact frequency per player*

Recording Session Type	Individual mean impact frequency (±SD)
MATCH	186 (74)
TRAINING	107 (55)

Impact Thresholds

We applied impact thresholds to categorise the impact forces. These thresholds were calculated from the 50th (small), 75th (medium) and 90th (large) percentiles of the match data sample and are an indication of what trends further data analysis might indicate. Threshold brackets needed to be exclusive to avoid repetitions of a singular impact therefore:

match

$$Large = p90\_match$$

$$Medium = p75\_match - p90$$

Table 3. *Cumulative impact force distribution*

	Impact Force Distribution (Team)					
	Cumulative Frequency (Linear)			Cumulative Frequency (Angular)		
Recording Session Type	LARGE	MEDIUM	SMALL	LARGE	MEDIUM	SMALL
MATCH	409	613	613	345	516	516
TRAINING	122	284	448	101	181	335
	Total match impacts = 4087* Total training impacts = 2285*			Total match impacts = 3443* Total training impacts =1684*		

*impacts <10 g and less than <4600 rads/s^2 classified as negligible

Impacts by Playing Position

Number of Impacts

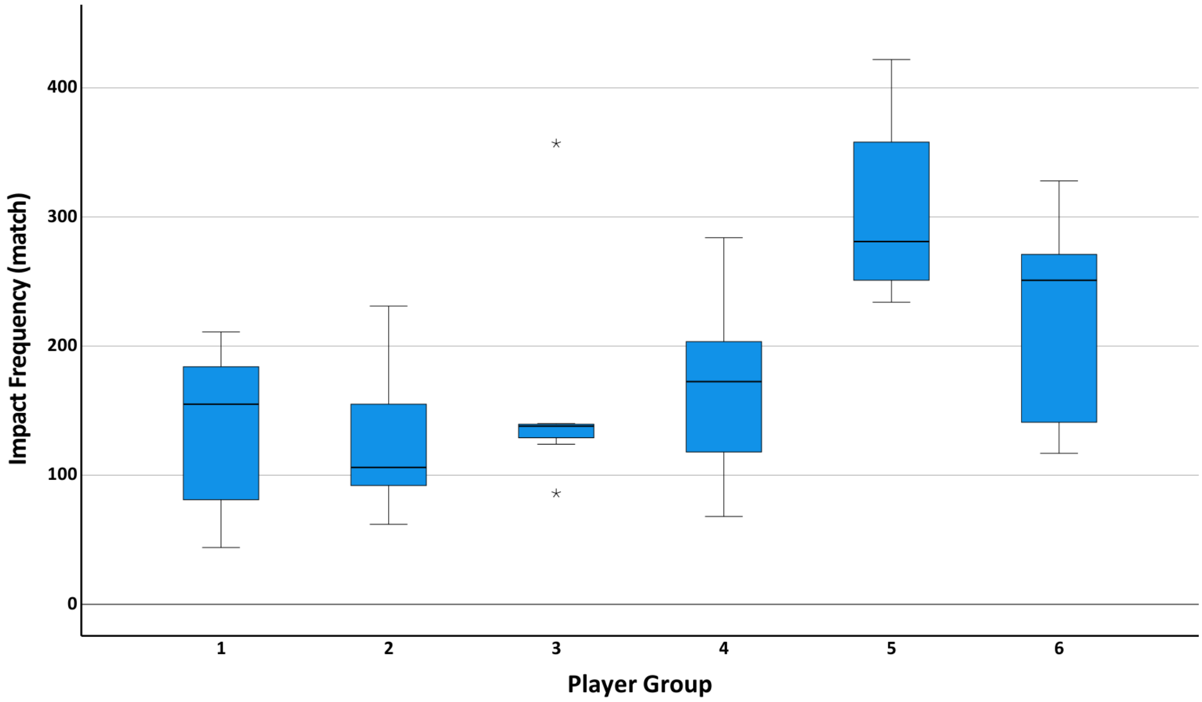

Figure 1. *Impact frequency by player group (match)*

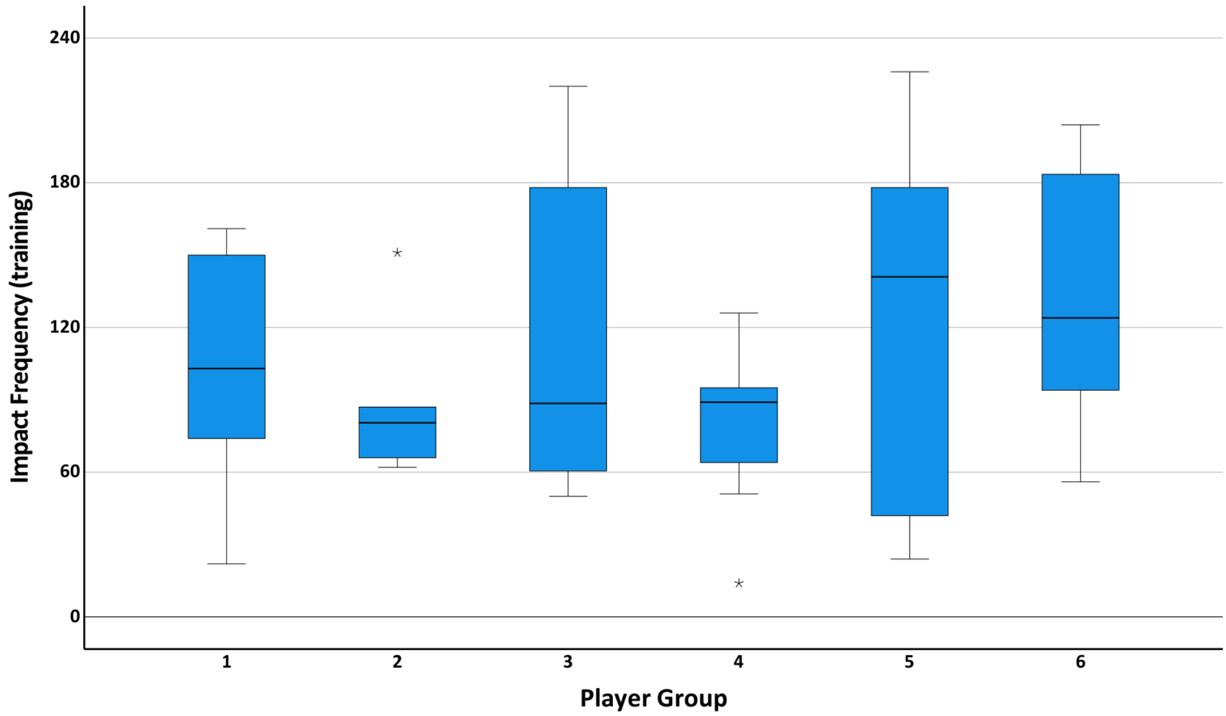

Figure 2. *Impact frequency by player group (training)*

Figure 1 and Figure 2 indicate the distribution of impacts (combined linear and angular) across the six player groups in matches and training.

Magnitude of Impacts

Table. 4. *Distribution frequency of mean impact force per player by player group (match)*

	Mean Linear Impact Distribution (±SD)			Mean Angular Impact Distribution (±SD)		
Player Group	LARGE	MEDIUM	SMALL	LARGE	MEDIUM	SMALL
1	4 (3)	12 (6)	17 (6)	5 (3)	10 (4)	15 (9)
2	6 (3)	13 (4)	13 (6)	5 (3)	10 (6)	16 (4)
3	8 (4)	17 (3)	12 (6)	6 (3)	10 (4)	17 (11)
4	2 (2)	10 (6)	18 (9)	5 (4)	8 (6)	12 (9)
5	30 (9)	22 (7)	25 (8)	24 (23)	20 (12)	15 (6)
6	4 (1)	15 (8)	21 (15)	4 (1)	8 (3)	10 (2)

Table. 5. *Distribution frequency of mean impact force per player by player group (training)*

	Mean Linear Impact Distribution (±SD)			Mean Angular Impact Distribution (±SD)		
Player Group	LARGE	MEDIUM	SMALL	LARGE	MEDIUM	SMALL
1	3 (2)	5 (3)	12 (7)	2 (1)	5 (4)	8 (4)
2	4 (2)	8 (4)	7 (5)	3 (3)	6 (1)	8 (2)
3	4 (3)	6 (4)	8 (4)	3 (3)	5 (3)	7 (3)
4	< 1 (0.8)	5 (3)	6 (3)	1 (1)	2 (2)	7 (3)
5	2 (1)	9 (6)	16 (16)	2 (1)	4 (2)	8 (4)
6	2 (3)	6 (2)	15 (14)	2 (2)	2 (2)	9 (5)

Example interpretation of Table 4 and Table 5:

> *'The average individual in player group 1 received 4(±3) large linear impacts, 12(±6) medium linear impacts and 17(±6) small linear impacts per match (Table. 4.). In addition, the average player group 1 individual also received 5(±3) large angular impacts, 10(±4) medium angular impacts and 15(±9) small angular impacts per match (Table. 5.)'*

Linear and angular impacts do not usually occur in isolation and so, a single impact event could result in sensors recording a linear and angular value.

<u>Linear Impacts</u>

Inter-group:

Player group 6 received significantly more *large* linear impacts than player group 4 during matches.

Player group 5 receive significantly more *large* linear impacts than all the other player groups during matches.

Intra-group:

Player group 3 received significantly more *medium* linear impacts in matches than in training.

Player group 5 received significantly more *large* and *medium* linear impacts in matches than in training.

<u>Angular Impacts</u>

Intra-group:

Player group 5 received significantly more *medium* angular impacts in matches than in training.

Player group 6 received significantly more *medium* angular impacts in matches than in training.

Considerations

This data is only a sample from the full study, representing two matches and two training days. Therefore, it may not be truly representative of the final outcomes of the main research study. At the writing of this report, head impact data has been collected at 19 matches and 13 training days (26 sessions). The data will be written for peer reviewed publication over the next 12 months.

The sensors are not able to record maximum linear impact forces that are >27g, although there is no cap on maximum measurement of angular impact forces. Positional corrections of the sensor to account for centre of gravity (COG) were not applied to the sample data.

The thresholds for *large, medium,* and *small* linear and angular impacts are generated from statistical indications rather than as a result of proven neurophysiological injury indications. The main study includes analysis of blood biomarkers of neurological trauma and the outcomes of this analysis will potentially provide greater insight into more appropriate thresholds based upon biomarkers.

Researchers: Dr Karen HInd, Mr Thomas Goodbourn and Mr Jonathan Frawley.

4) Comment on research funding

We have found it challenging to secure funding for research in this field. Few grant calls are open to concussion research, particularly in sport. To date, most of our research has been conducted with no, or very little external funding. For example, the UK Rugby Health project received no external funding outside of that provided by small funding from AUT and Durham University, and Dr Doug King has been leading research on the measurement of head impacts for over 6 years, also with no external funding support. With funding, we could deliver more timely research findings and perform more advanced analysis. We believe there are benefits to co-designing research with sports codes to ensure relevance, but research must be fully transparent and publicly available, no matter what the findings are.

Dr Karen Hind, Prof Patria Hume, and Dr Doug King.