AUT MILLENNIUM | AUT SPORTS PERFORMANCE RESEARCH INSTITUTE NEW ZEALAND

RUGBY CODES RESEARCH GROUP – FACT SHEET

Head impact biomechanics and sports-related concussion research

Dr King has completed six studies using head impact accelerations since 2014 with senior and junior rugby union (NZ), junior rugby league (NZ), wrestling (USA) and semi-professional Australian Rules football (Australia).

Head impact accelerations recorded range from:

- **Senior rugby union**: 563 +/- 618 per-match or 95 +/-133 impacts per-player per-match; Linear accelerations 22.2 +/-16.2*g*; Rotational accelerations 3,902.9 +/-948.8 rads/s^2
- **Junior rugby union** (U9): 46 [37-58] per-match resulting in 10 [4-18] impacts per-player per-match; Linear accelerations 15*g* [12-21]*g*; Rotational accelerations 2,296 [1,532-4,152] rads/s^2
- **Junior rugby league** (U11): 116 per-match resulting in 13 impacts per-player per-match; Linear accelerations 16*g*, Rotational accelerations 2,773 rads/s^2
- **Wrestling**: 41 +/- 4 impacts over tournament; Linear accelerations 15*g*; Rotational accelerations 1,880 rads/s^2
- **Australian Rules Football**: 407 +/- 143 impact per-match resulting in 30 +/- 38 impacts per-player per-match; Linear accelerations 13*g*; Rotational accelerations 1,556 rads/s^2

Dr Doug King has led head impact biomechanics and sports-related concussion research in New Zealand.

Dr King is a registered comprehensive nurse with 28 yrs. experience in medical, surgical, orthopaedics, mental health, and emergency nursing. Dr King is now Clinical Nurse Specialist in minor injuries at Lower Hutt hospital where he regularly sees patients who have sustained sports-related concussions. Dr King also provides regular sports medic sideline service to rugby union, rugby league and netball games in Wellington.

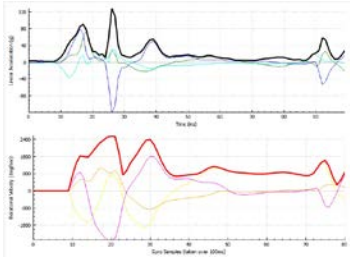
Dr King's two PhDs with AUT examined the epidemiology of rugby union and rugby league injuries, and then the biomechanics of head impacts using accelerometer via ear patch and mouthguard technology.

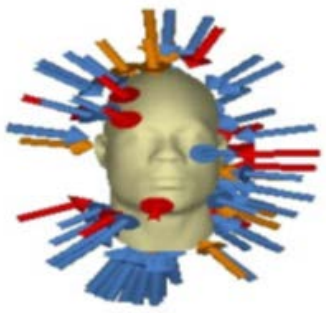
Dr Doug King
NZOSM, NZGSM(IO), NZDSM(R), PhD[1], PhD[2], MHealSc (credit), Dip Football Med (FIFA) PGDipSportsMed (credit), PGCertHealSc (Resus), PGCertHSc (SportsMed),

Dr King is a retired serviceman from the Royal New Zealand Navy (1977-1987) and Royal New Zealand Nursing Corps (1995-2000). He was awarded the NZOSM, NZGSM(IO) and NZDSM(R) medals, was the recipient of the Te Amorangi National Māori Academy Excellence Award, the PhD New Investigator Award at AUT University and the Faculty of Health and Environmental Sciences PhD Award for translation of thesis to publication.

Dr King is co-leader of the SPRINZ Rugby Codes Research Group, an Honorary Research Fellow at the Applied Sports, Technology, Exercise and Medicine (A-STEM) Research Centre, College of Engineering at Swansea University, and a Research Associate of the Sports Performance Research Institute of New Zealand (SPRINZ) at AUT.

Dr King has produced 51 peer reviewed publications, 29 conference presentations and 1 book.





Head impact telemetry research published, undertaken and ongoing

King, D.A., Hume, P.A., Brughelli, M. and Gissane, C. **Instrumented mouthguard acceleration analyses for head impacts in amateur rugby union players over a season of matches.** *American Journal of Sports Medicine*, 2015, **43**(3); 614-624

Background: Direct impacts with the head (linear acceleration or pressure) and inertial loading of the head (rotational acceleration or strain) have been postulated as the two major mechanisms of head related injuries such as concussion. Although data are accumulating for soccer and American football there are no published real-time data for non-helmeted collision sports such as rugby union.

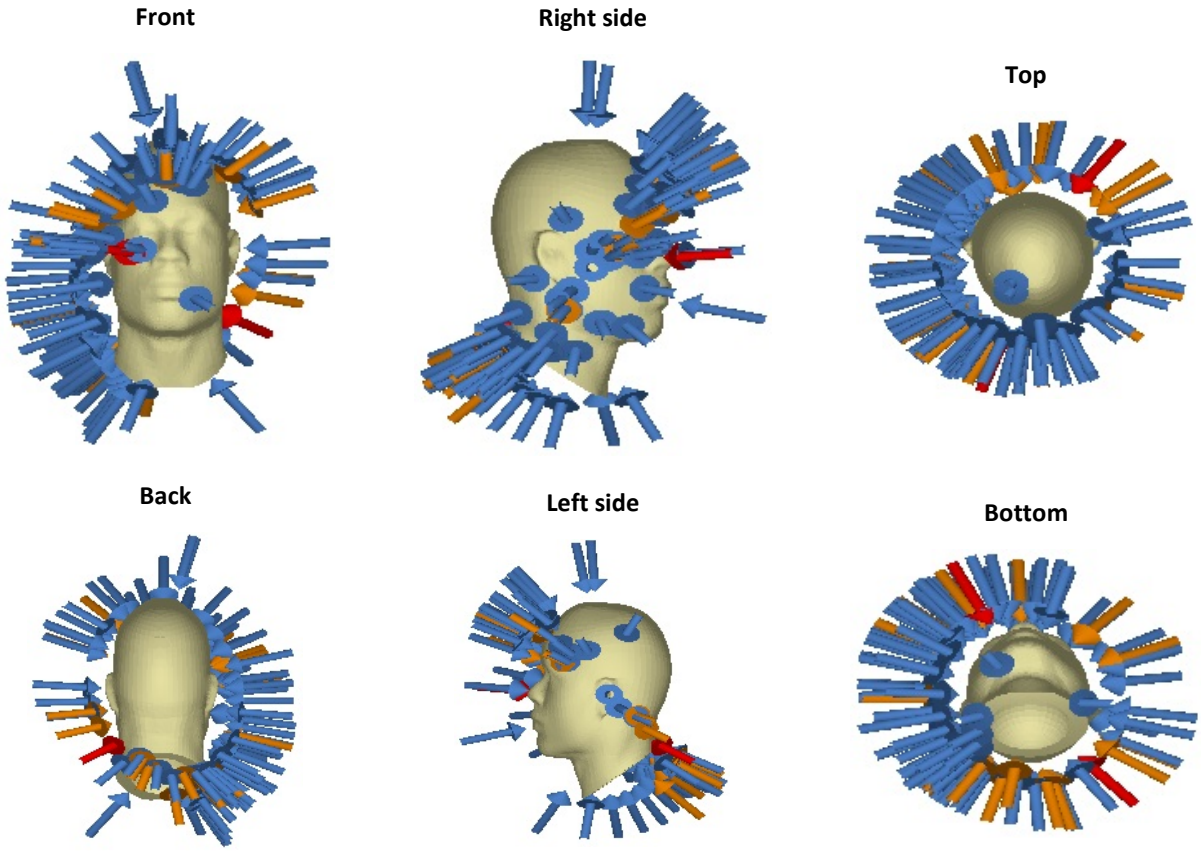
Purpose: To quantify head impacts via instrumented mouthguard acceleration analyses for rugby union players over a season of matches.

Study Design: Cross-sectional study.

Methods: Data on impact magnitude and frequency were collected with moulded instrumented mouthguards worn by thirty eight premier amateur senior rugby players participating in the 2013 domestic season of matches.

Results: A total of 20,687 impacts >10*g* (range 10.0-164.9*g*) were recorded over the duration of the study. The mean number of impacts per player over the duration of the season of matches was 563 ±618 resulting in a mean of 95 ±133 impacts to the head per player, per match over the duration of the season of matches. The impact magnitudes for linear accelerations were skewed to the lower values (S_p=3.7 ±0.02; p<0.001) with a mean linear acceleration of 22.2 ±16.2*g*. Rotational accelerations were also skewed to the lower values (S_p= 2.0 ±0.02; p<0.001) with a mean rotational acceleration of 3,902.9 ±3,948.8 rad/s^2.

Conclusion: The acceleration magnitudes and number of head impacts in amateur rugby union players over a season of matches measured via instrumented mouthguard accelerations, were higher than for most sports previously reported. Mean linear acceleration measured over a season of matches was similar to the mean linear accelerations previously reported for youth American football players, high school American football players, and collegiate American football players, but lower than female soccer youths. Mean rotational acceleration for measured over the a season of matches was similar to for youth American football players, high school American football players, and collegiate American football players, but less than female soccer youths, concussed collegiate American football players and professional American football players.



King, DA., Hume, P.A, Gissane, C., Brughelli, M. and Clark, T. **The influence of head impact threshold for reporting data in contact and collision sports: Consensus needed.** *Sports Medicine*. **46**(2): 151-169

Background: Head impacts and resulting head accelerations cause concussive injuries. There is no standard for reporting head impact data in sports to enable comparison between studies.

Objective: To outline methods for reporting head impact acceleration data in sport and the effect of the acceleration thresholds on the number of impacts reported.

Methods: A systematic review of accelerometer systems utilised to report head impact data in sport. Calculation of the effect of using different thresholds on a set of impact data from 38 amateur senior rugby players in New Zealand (NZ) over a competition season.

Results: Of 52 studies identified, 42% reported impacts using >10*g* threshold. Studies reported descriptive statistics as mean ±standard deviation, median, 25th to 75th interquartile range, and 95th percentile. Application of the different impact thresholds to the NZ data set resulted in 20,687 impacts >10*g*; 11,459 (45% less) impacts >15*g*; and 4,024 (81% less) impacts >30g.

Discussion: Linear and angular raw data were most frequently reported. Metrics combining raw data may be more useful, however validity of the metrics has not been adequately addressed for sport. Differing data collection methods and descriptive statistics for reporting head impacts in sports limits inter-study comparisons. Consensus on data analysis methods for sports impact assessment is needed, including impact reporting thresholds. Based on the available data, the 10*g* threshold is the most commonly reported impact threshold and should be reported as the median with 25th and 75th interquartile ranges as the data is non-normal distributed. Validation studies are required to determine the best threshold and metrics for impact acceleration data collection in sport.

Conclusion: Until in-field validation studies are completed, it is recommended that head impact data should be reported as median and interquartile ranges using the 10*g* impact threshold.

King, D., Hecimovich, M., Clark, T. & Gissane. **Measurement of the head impacts in a sub-elite Australian Rules football team with an instrumented patch: An exploratory analysis.** *International Journal of Sports Science and Coaching*, 2017. In print

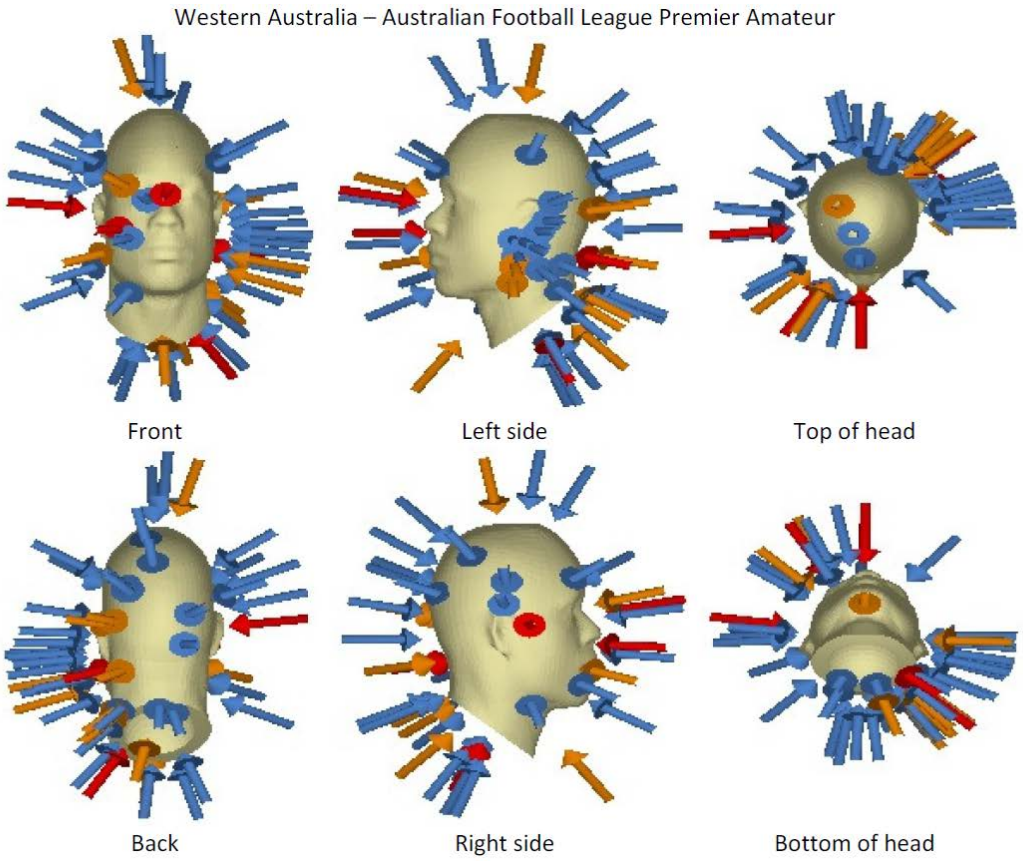
Aim: To investigate the frequency, magnitude and distribution of head impacts in Australian Football League players over a season of matches.

Methods: A prospective cohort analysis of impact magnitude, frequency and distribution on data collected with a wireless head impact sensor worn behind the ear of 23 players.

Results: A total of 4,903 impacts were recorded. Players experienced on average 407 ±143 impacts over the duration of the study resulting in 30 ±38 impacts per-player per-match. Linear accelerations ranged from 10*g* to 153*g* with a mean, median and 95th percentile value of 17*g*, 13*g* and 40*g* respectively. Rotational accelerations ranged from 130 rad/s^2 to 21,890 rad/s^2 with a mean, median and 95th percentile value of 2,426 rad/s^2, 1,556 rad/s^2 and 7,571 rad/s^2 respectively.

Discussion: This study obtained initial measurements on the frequency, magnitude, distribution and risk weighted exposure of head impacts in Australia Rules Football in order to better inform medical personnel in the identification and evaluation of at-risk players for concussion. The location of impacts varied considerably with the back of the head recording more total impacts than the front, side and top. Midfielders sustained more impacts per-player, per-match, and had higher median resultant linear accelerations than forwards and defenders.

Conclusions: The results of this study, in which most impacts were within the low severity limit for linear, rotational, HIT_{SP} and RWE_{CP}, indicate that ARF needs to include more encompassing methods of examination of player exposure



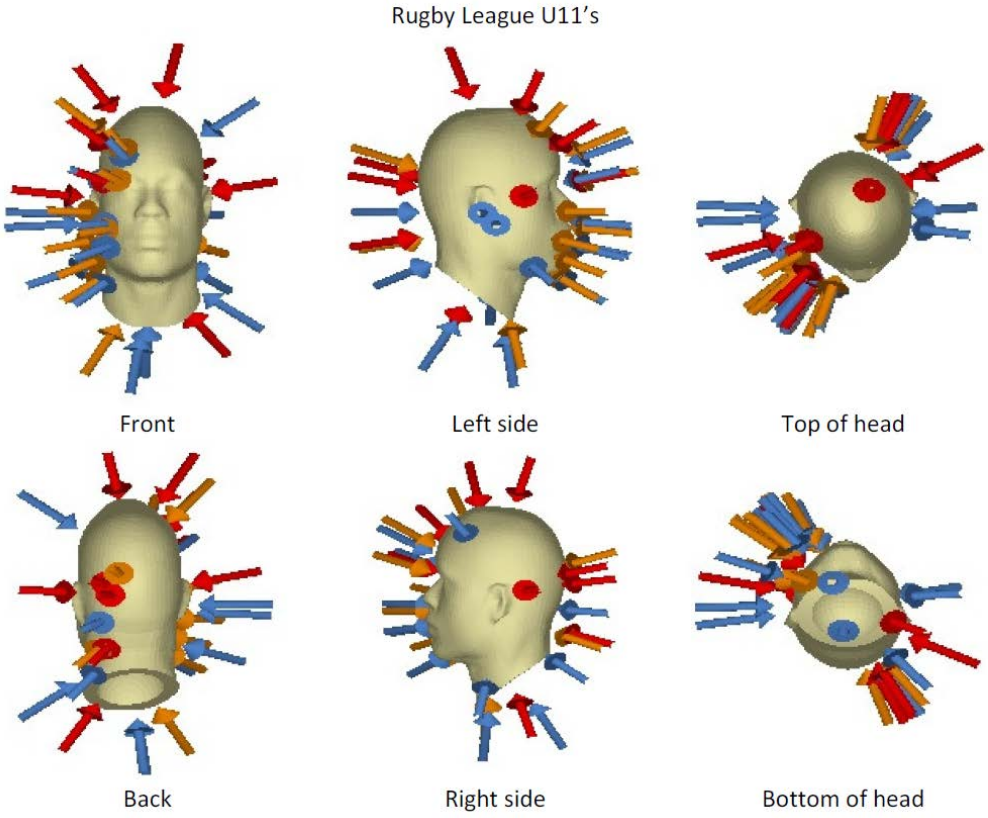
King, D., Hume, P., Gissane, C. & Clark, T. **Head impacts in a junior rugby league team measured with a wireless head impact sensor: An exploratory analysis.** *Journal of Neurosurgery: Pediatrics*, 2016. doi: 10.3171/2016.7.PEDS1684

Aim: To investigate the frequency, magnitude and distribution of head impacts in junior rugby league players over a season of matches.

Method: A prospective cohort analysis of impact magnitude, frequency and distribution on data collected with instrumented XPatches worn behind the ear of 17 players in an under-11 junior rugby league team.

Results: A total of 1,977 impacts were recorded. Players experienced on average 116 impacts over the duration of the study resulting in 13 impacts per-player per-match. Linear accelerations ranged from 10 *g* to 123 *g* with a mean, median and 95th percentile value of 22 *g*, 16 *g* and 57 *g* respectively. Rotational accelerations ranged from 89 rad/s^2 to 22,928 rad/s^2 with a mean, median and 95th percentile value of 4,041 rad/s^2, 2,773 rad/s^2 and 11,384 rad/s^2 respectively.

Conclusions: The frequency, magnitude and distribution of head impacts of junior rugby league players experienced during match participation was characterized. The level of impact severity based on the magnitude of impacts for linear and rotational accelerations recorded was similar to the impacts reported in American junior and high school football, collegiate football and youth ice hockey players. However the players in the rugby league cohort were younger, had less body mass and played at a slower speed than the American players. Junior rugby league players are required to tackle the player to the ground and utilise a different tackle technique than American football, likely increasing the rotational accelerations recorded at the head.



King, D., & Hume, P., Gissane, C., & Clark, T. **Similar head impact acceleration measured using instrumented ear patches in a junior rugby union team during matches in comparison with other sports.** *Journal of Neurosurgery: Pediatrics*, 2016. **18**(1):65-72

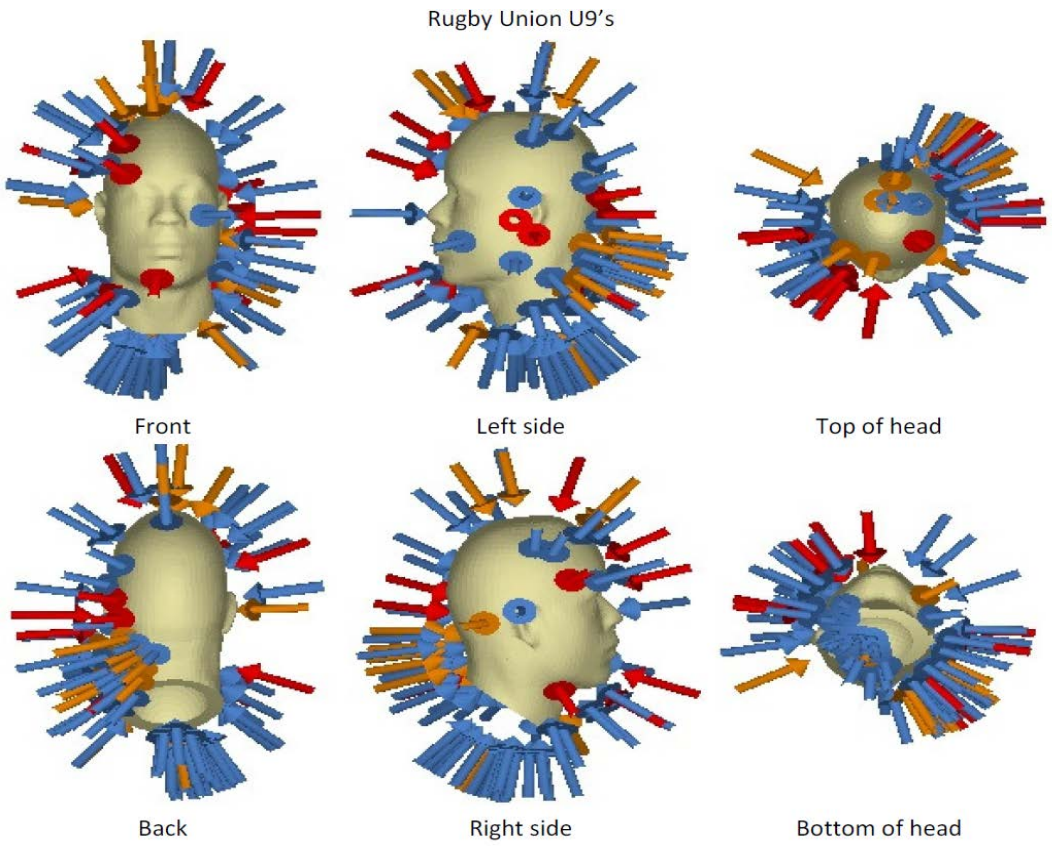
Background: Direct impacts with the head and inertial loading of the head have been postulated as major mechanisms of head-related injuries such as concussion.

Object: A descriptive observational study was conducted to quantify head impact acceleration characteristics in under-9 year old junior rugby union players in New Zealand.

Methods: The impact magnitude, frequency and location were collected with a wireless head impact sensor worn by 14 junior rugby players participating in four matches.

Results: A total of 721 impacts >10*g* were recorded. The median [IQR] number of impacts per player was 46 [37-58], resulting in 10 [4 to 18] impacts to the head per player, per match. Median impact magnitudes recorded were 15*g* [12 to 21*g*] for linear accelerations and 2,296 [1352 to 4,152] rad/s^2 for rotational accelerations.

Conclusion: There were 121 impacts (16.8%) above the rotational injury risk limit and one (0.1%) impact above the linear injury risk limit. Acceleration magnitudes and number of head impacts in junior rugby union players were higher than similar age group sports participants previously reported. Median linear accelerations for the under-9 year old rugby players were similar for 7 to 8 year old American football players but lower than 9 to 12 youth American football players. The median rotational accelerations measured were higher than the median and 95th percentiles in youth, high school and collegiate American football players.



Hecimovich, M., King, D. & Garrett, T. **Head impacts as a result of participation in amateur wrestling: An exploratory analysis.** *International Journal of Wrestling Science.*2017 In print

Purpose: The aim of this exploratory study was to investigate the frequency, magnitude and distribution of head impacts greater than 10 g with the use of wireless head impact sensors over a single tournament in a small sample of adult collegiate wrestlers.

Methods: Three participants wore an impact-sensing skin patch on their mastoid process during each match. The patch contained a low-power, high-g triaxial accelerometer with 200 g maximum per axis and a triaxial angular rate gyroscope to capture linear and rotational time history accelerations of the heads center of gravity for all impacts that occurred during the matches. Head impact exposure including frequency, magnitude and location of impacts were quantified using previously established methods. Two measures of impact frequency were computed for each participant: impacts per match, the total and average number of impacts per match for all matches; participant group impacts, the total and average number of recorded head impacts for the three participants' groups for all matches. Head impacts were assessed for injury tolerance level for a concussion occurring using previously published injury tolerance levels for linear (>95 g) and rotational acceleration (>5,500 rad/s2). Head impacts were assessed for impact severity using previously published levels for linear acceleration (mild <66 g, moderate 66-106 g, severe >106 g) and rotational acceleration (mild <4,600 rad/s2, moderate 4,600-7,900 rad/s2, severe >7,900 rad/s2).

Results: Participants averaged 41 ± 4 impacts with a resultant median peak linear and rotation acceleration of 15 g and 1,880 rad/s2 resulting in a median HITSP and the RWECP of 15 and 0.0004, respectively. The location of impacts varied considerably with more head impacts to the front of the head than the back and top.

Conclusions: Due to the exploratory nature of this study, small sample size and the absence of a diagnosed concussion, the results are to be viewed with caution, as it is unclear of the generalizability of the data. Results indicate lower levels in all measurements compared to football and rugby. Interestingly the back of the head recorded higher median peak linear accelerations then the side that may be the result of takedown manoeuvres. This may have also contributed to the higher median RWECP of the top right side of the head than of the front right side. The key to this study was obtaining and thus gaining initial measurements on the frequency, magnitude, distribution and risk weighted exposure of head impacts in collegiate wrestling in order to assist in the identification of at-risk wrestlers and better inform medical personnel of the need to evaluate an athlete for concussion.

The above paper was presented to the International Scientific and Professional Conference on Wrestling organized by the Faculty of Kinesiology, University of Zagreb and the Faculty of Sports and Physical Education, University of Novi Sad and under the auspices of the International Network of Wrestling Researchers (INWR), the United World Wrestling (UWW) and the International Association of Sport Kinetics (IASK) held at the Faculty of Sports and Physical Education in Novi Sad, Zagrib, Serbia in 2017 (ISBN: 978-86-6353-022-5).

Other head impact telemetry research undertaken

King, D., Hume, P., Gissane, C., Kieser, D. & Clark, T. Impacts to the head from match participation in women's rugby league over one season of domestic competition. *Submitted to Journal of Science and Medicine in Sport.* (2016)

King, D., Hume, P., Gissane, C., Kieser, D. & Clark, T. Impacts to the head from match participation in women's rugby league over one season of domestic competition. *To be submitted*

King, D., Hume, P., Gissane, C., & Clark, T. Measurement of head impacts in a senior amateur rugby league team with an instrumented patch: Exploratory analysis. *To be submitted.*

King, D., Hume, P., Gissane, C., & Clark, T. Impacts to the head in a premier one domestic netball team measured with a wireless head impact sensor over a domestic competition: an exploratory analysis. *To be completed.*

Other head impact research ongoing

King, D., Hume, P., Gissane, C., & Clark, T. Head impacts in an under 19 representative netball team partaking in regional and national competitions over one year.