

CONCUSSION IN PROFESSIONAL RUGBY LEAGUE

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DECLARATION

This thesis is submitted to the University of Newcastle in fulfilment of the requirements for the degree of Doctor of Philosophy.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library**, being made available for loan and photocopying subject to the provisions of the Copyright Act 1968.

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I hereby certify that the work embodied in this thesis has been completed in collaboration with other researchers. I have included as part of the thesis a statement clearly outlining the extent of collaboration, with whom and under what auspices.

I hereby certify that this thesis is in the form of a series of published papers of which I am a joint author. I have included as part of the thesis a written statement for each co-author, endorsed by the Faculty Assistant Dean (research Teaching), attesting to my contribution to the joint publication.

I acknowledge that the intellectual content of this thesis is the product of my own work, except to the extent that others have contributed in terms of the study conception and design. Contributions in terms of editorial suggestions have also been offered by my supervisors and other colleagues.

Andrew J. Gardner

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The views and conclusions contained here are those of the author and should not be interpreted as necessarily representing the official policies or endorsements of The University of Newcastle, The National Rugby League (NRL), or any of the funding or supporting bodies acknowledged above.

ABSTRACT

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Concussion in Professional Rugby League

Background

Rugby League is a popular full-contact sport played internationally by 18 full-member test nations of the Rugby League International Federations (RLIF), 21 RLIF affiliate-members, and approximately 32 other unaffiliated nations. The most popular elite, professional, domestic leagues are played in Australia and the United Kingdom. Rugby league game play involves numerous collisions and tackles, and it carries an inherent risk for injury including head trauma. Despite the increased interest in sport-related concussion in recent years, only a limited number of studies have been conducted in rugby league players on this topic, with the large majority of publications only addressing the incidence of concussion as a secondary outcome measure within sports-specific injury focused studies. Additionally, there are currently no published papers on the potential long-term consequences of sport-related concussion in retired professional rugby league players.

Aim/Purpose

This thesis addresses some of the issues related to the identification and acute management of sport-related concussion in professional rugby league players. It also examines the potential long-term consequence of concussion in retired professional rugby league players. One of the overall aims of this thesis was to conduct a systematic review of the literature examining both, (i) concussion in rugby league; and (ii) the use of magnetic resonance spectroscopy in sport-related concussion. These systematic review papers set the scene for the main aims of this thesis, which were to address the identified gaps in the literature, first by identifying the factors associated with concussion in rugby league at the professional level via systematic video analysis of the injury. The purpose of this first study was to described player and injury characteristics, situational factors, concussion signs, and return to play. A secondly aim was to examine the potential long-term consequences of a history of multiple concussions in retired professional rugby league players. The purpose of this second study was to examine the brain neurometabolite concentrations and the cognitive profiles of retired rugby league players who had a history of numerous self-reported concussions.

Methods

Paper 1: This systematic review involved the retrieval of eligible studies pertaining to concussion in rugby league players. Numerous online databases were searched for publication in English from 1900 up to June 2013 using the key search terms: rugby league, league, football; in combination with injury terms: athletic injuries, concussion, sports concussion, sports related concussion, brain concussion, brain injury, brain injuries, mild traumatic brain injury, mTBI, traumatic brain injury, TBI, craniocerebral trauma, head injury, and brain damage. Articles were regarded as relevant and warranting inclusion if they were experimental studies examining concussed rugby league players. Studies were included whether they were conducted with acute or long-term concussed athletes (i.e., there were no restrictions placed on time elapsed since injury).

Paper 2: All National Rugby League clubs were invited to participate in this video analysis study of concussion, three agreed to participate. All players medically diagnosed with a concussion by an experienced team physician from the three participating clubs were included in the study. The digital video footage of games in which each concussion was diagnosed was reviewed. Descriptions pertaining to player's demographic information (i.e., age, height, weight, playing position, and game performance statistics) and return to match play were also recorded. Two raters independently viewed the digital records of events leading to concussion. Relevant variables were pre-determined and data were independently recorded by both raters. In order to reach consensus, all discrepancies between raters resulted in a review of the footage together and a discussion regarding the recorded data. Under circumstances where consensus was not reached, a third rater was to be consulted to make the final determination, however this was not required.

Paper 3: Each use of the 'Concussion Interchange Rule' ('CIR') during the 2014 National Rugby League season was included in the study. There was no video analysis conducted on any event that was not logged and assessed by club medical staff. Access to video footage of the incident was attained through the National Rugby League's Digital Press Pass subscription. All uses of the CIR were independently reviewed by the first author and at least one other author. Two authors were blinded to the study hypotheses but the first author was not blinded. The three raters determined whether any of six signs (loss of consciousness, loss of muscle tone, seizures, clutching of the head, unsteadiness of gait, or possible impairment in cognition or awareness as evidenced by a blank or vacant stare) were present, absent, or indeterminable based on the available footage of the incident for every case. When there was disagreement between the two primary raters (who rated all incidents), both raters reviewed

and discussed those cases in an effort to reach consensus. In the cases where consensus could not be achieved, ratings from a third rater were used.

Paper 4: This systematic review involved the retrieval of eligible studies pertaining to magnetic resonance spectroscopy and concussion in athletes. Numerous online databases were searched for publication in English up to February 2013 using the key search terms: magnetic resonance spectroscopy, nuclear magnetic resonance spectroscopy, neurospectroscopy, spectroscopy, two-dimensional nuclear magnetic resonance spectroscopy, correlation spectroscopy, J-spectroscopy, exchange spectroscopy, nuclear overhauser effect spectroscopy, NMR, MRS, COSY, EXSY, NOESY, 2D NMR, craniocerebral trauma, mild traumatic brain injury, mTBI, traumatic brain injury, brain concussion, concussion, brain damage, sport, athletic, and athlete. Articles were regarded as relevant, and warranting inclusion in the review if they were experimental studies using MRS to determine the presence (or absence) of pathophysiology in concussed athletic samples. Studies were included whether they were conducted acutely or post-acutely (i.e., there were no restrictions placed on time since injury) and whether or not they also used other outcome measures (e.g., conventional MRI, CT, symptom checklists, balance testing, or neuropsychological testing). All retrieved articles were independently assessed for quality using a standardized quality assessment checklist.

Paper 5: Retired professional rugby league players (n=13) were recruited through communication with the club alumni. Exclusion criteria included any medical history of neurosurgery, or any history of a brain tumor requiring radiation treatment, or claustrophobia. Healthy community control subjects similar in age and education were recruited through a research participant registry established by a medical research institute. All participants completed a clinical interview and neurocognitive testing. The total interview and testing time was approximately 135 minutes. The MRS data was collected during a separate, single testing session on all participants as one component of a multiparametric neuroimaging study. The imaging time for the MRS component of the study was approximately 25 minutes; the whole multiparametric acquisition time was approximately 65 minutes. An overall test battery mean was computed by summing and averaging the normative scores (expressed in T score units with a mean of 50 and a SD of 10). Conventional Imaging was performed on a 3 T Siemens Skyra scanner with a 20-channel head coil. MRS voxels were placed in posterior cingulate grey matter (GM) and parietal white matter (WM). Concentrations of glutamate (Glu), glutathione (GSH), *myo*-inositol (mI), *N*-acetylaspartate (NAA), total choline (tCho), creatine+phosphocreatine (tCr), and glutamate+glutamine (Glx) were quantified using LCModel and water scaling.

Results

The systematic review of the rugby league literature identified that very little research had been conducted evaluating concussion. One hundred and ninety nine rugby league injury publications were identified. Thirty-nine (20%) were related in some way to concussion. Of the 39 identified articles, 6 (15%) had the main aim of evaluating concussion, while the other 33 reported on concussion incidence as part of overall injury data analyses. Rugby league concussion incidence rates vary widely from 0.0 to 40.0/1000 playing hours, depending on the definition of concussion injury (game time loss vs. no game time loss). The incidence rates vary across match play versus training session, seasons (winter vs. summer) and playing position (forwards vs. backs). The ball carrier has been found to be at greater risk for injury than tacklers. Concussion accounts for 29% of all injuries associated with illegal play, but only 9% of injuries sustained in legal play.

Video analysis of medically diagnosed concussions during the 2013 National Rugby League (NRL) season identified most concussions (83%) occurred during a high tackle, and all concussed ball carriers were hit high. None of the striking players were concussed. All concussions involved a blow to the head or face. Loss of consciousness was observed in 30% of cases. Only half of the total sample was removed from play, and one athlete who was removed returned to play in the same match. Of the players who were removed from play, the large majority returned to play the following week. Illegal play accounted for 25% of all concussions. The concussion incidence was 14.8 injuries per 1,000 player NRL match hours or approximately one concussion every four games.

The video analysis of the use of the concussion interchange rule (CIR) during the 2014 season identified 167 uses of the CIR. Loss of consciousness was observed in 30.2% of cases. Common observable signs of injury included clutching the head (69.1%), loss of muscle tone (50.0%), unsteadiness of gait (52.5%), and a blank or vacant state (59.9%). Convulsive convulsions were observed in 1.9%. The overall inter-rater reliability for these concussion signs for the two raters was $\kappa = 0.60$ (95% CI = 0.56-0.64), which is considered to be weak to moderate agreement. More than half of the players who used the CIR returned to play later in the same match (56.8%). Of the players who used the CIR, and who had three or more observable signs of possible injury, 46.4% returned to play in the same game. No player used the CIR more than once in the same game. Of the players who were removed from play, the large majority returned the following week. Forwards (69.9%) used the CIR significantly more often than backs (30.1%). Most incidences occurred from a hit up (62.3%) and occurred during a high tackle (80%). The incidence rate was 24.03 uses of the CIR per 1,000 NRL player match hours. This equates to approximately one CIR every 2.41 games in the 2014

NRL season.

The systematic review of magnetic resonance spectroscopy (MRS) in sport-related concussion identified only eleven publications, with varying methodology and results. The review identified 11 publications that met criteria for inclusion, comprised of data on 200 athletes and 116 controls. Nine of 11 studies reported a MRS abnormality consistent with an alteration in neurochemistry. The results support the use of MRS as a research tool for identifying altered neurophysiology and monitoring recovery in adult athletes, even beyond the resolution of post-concussive symptoms and other investigation techniques returning to normative levels.

In new data collected as part of the thesis, the MRS profiles of retired NRL players differed compared to community age- and education-matched control participants. From a clinical perspective, these early middle-aged retired athletes did not report more depression, anxiety, or stress, and they did not have worse cognitive functioning, than control subjects (although one retired player met clinical criteria for mild cognitive impairment [MCI]). They did, however, perform more poorly than controls on non-dominant fine motor coordination and speed, and their balance scores were correlated with lower levels of some neurometabolites. A significant difference between groups was observed in grey matter N-acetylaspartate (NAA), with significantly lower concentrations of NAA found in retired athletes. No significant differences were found in white matter NAA. Secondary analysis found a significant difference between groups in grey matter myo-inositol (mI), with retired players having lower concentrations compared to controls. There was a significant difference in grey matter glutathione, with retired players showing lower concentrations compared to controls. There were no significant difference between groups in grey matter choline or glutamate concentrations. In white matter, there were no statistically significant differences in any of the neurometabolites that were hypothesized to differ (mI, choline, glutamate, or glutathione).

Conclusion

Rugby league is a contact sport with high incidence of concussions, which leads to participants being exposed to numerous concussions during their careers. The current series of studies adds enormously to rugby league concussion literature, which had previously been quite limited, as identified in the systematic review of the rugby league concussion literature (Chapter 2). The current series of studies characterised concussion at the professional level in current rugby league players; identifying antecedent events and risk factors, together with return to play management and decision-making. In addition to investigating current players, this series of studies also investigated cognition and neurometabolites in retired professional rugby league players. While the current series of studies identifies concussion as a common

risk factor for participation in rugby league, the potential long-term consequences for rugby league players with a history of numerous concussions remains a topic requiring further investigation. In the small sample of retired players included in Study 3, not one player expressed significant concerns regarding their cognition and on neuropsychological assessment none of the retired rugby league players performed significantly below their estimated pre-morbid level of intellectual function. So for all intents and purposes the investigation was conducted in ‘asymptomatic’ retired rugby league players, however there were significant neurometabolic differences observed between groups on magnetic resonance spectroscopy. The clinical relevance of this finding also requires further investigation, but it may suggest that MRS is sensitive to possible pre-clinical symptomology that other methodologies (i.e., neuropsychological testing) are not sufficiently sensitive to detect.

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All errors and limitations remaining in this thesis are mine alone.

*“If our brains were so simple that we could understand them,
we would be so simple that we could not”*

- Anonymous

“If you cannot explain it simply, you do not understand it well enough”

-Albert Einstein

“Learning without thought is labour lost”

-Confucius

*The more you know, the more you realise how much you don't know – the less you know the
more you think you know*

-David T. Freeman

“A job well done is its own reward”

-Anonymous

“If the map differs from the terrain, believe the terrain”

- Norse proverb

*“Far and away the best prize that life offers is the chance
to work hard at work worth doing”*

- Theodore Roosevelt

*He will keep in perfect peace...
all those who trust in Him...
whose thoughts turn often to the Lord*

- Isaiah 26:3

PREFACE

PUBLICATIONS & PRESENTATIONS

RELATED PUBLICATIONS PUBLISHED IN PEER-REVIEWED JOURNALS RELEVANT TO THE TOPIC BUT NOT INCLUDED AS CHAPTERS IN THE THESIS:

Iverson GL, Gardner AJ, McCrory P, Zafonte R, & Castellani R. (2015). A critical review of chronic traumatic encephalopathy. *Neuroscience & Biobehavioral Reviews*, in press.

Gardner A, Iverson GL, & McCrory, P. (2014). Chronic traumatic encephalopathy in sport: a systematic review. *British Journal of Sports Medicine*, 48 (2), 84-90.

Gardner AJ, Iverson GL, Williams WH, Baker S, & Stanwell, P. (2014). A systematic review and meta-analysis of concussion in rugby union. *Sports Medicine*, online first August, 20.

Gardner AJ, Tan CO, Ainslie PN, van Donkelaar P, Stanwell P, Levi CR, & Iverson GL. (2014). A Systematic Review of Cerebrovascular Reactivity After Sport-Related Concussion. *British Journal of Sports Medicine*, accepted October, 2014.

Schofield PW, Moore TM, & Gardner A. (2014). Traumatic brain injury and olfaction: a systematic review. *Frontiers in Neurology: Neurotrauma*, 5 (Art. 5).

Gardner A. (2013). The complex clinical issues involved in an athlete's decision to retire from collision sport due to multiple concussions: a case study of a professional athlete. *Frontiers in Neurology: Neurotrauma*, 4 (Art.141), 1-6.

Gardner A, Kay-Lambkin FJ, Stanwell P, Donnelly JD, Williams WH, Hiles A, Schofield PW, Levi CR, & Jones DK. (2012). A Systematic Review of Diffusion Tensor Imaging Findings in Sports-Related Concussion. *Journal of Neurotrauma*, 29 (16), 2521-2538.

REVIEWED ABSTRACTS PUBLISHED IN CONFERENCE PROCEEDINGS:

Gardner AJ, Iverson GL, Wojtowicz M, Levi CR, Makdissi M, Quinn TN, Shultz SR, Wright D, Stanwell P. (2015). *A Systematic Video Analysis of Concussion in the National Rugby League* presented at the *American Academy of Neurology 67th Annual Meeting*, April 18- 25, 2015; Washington, DC, USA.

Gardner AJ, Iverson GL, Wojtowicz M, Levi CR, Kay-Lambkin F, Schofield PW, Zafonte R, Shultz SR, Lin AP, Stanwell P. (2015). *Magnetic Resonance Spectroscopy Findings in Retired Professional Rugby League Players* presented at the *3rd Annual Sports Neuropsychology Concussion Symposium*, May 1-2; Atlanta, GA, USA.

Gardner AJ, Wojtowicz M, Levi CR, Zafonte R, Iverson GL. (2015). *Sports Concussion Assessment Tool – Third Edition (SCAT-3) for Screening Players Suspected of Concussion in the National Rugby League* presented at the *3rd Annual Sports Neuropsychology Concussion Symposium*, May 1-2; Atlanta, GA, USA.

Gardner AJ, Stanwell P, Ellis J, Levi CR, Iverson GL. (2015). *A Video Analysis of Use of the New ‘Concussion Interchange Rule’ in the National Rugby League During the 2014 Season* presented at the *5th International Neuropsychological Society/ Australian Society for Brain Injury Pacific Rim Conference*, July 1-4; Sydney, NSW, Australia.

CONFERENCE PRESENTATIONS:

Gardner AJ, Iverson GL, Wojtowicz M, Levi CR, Makdissi M, Quinn TN, Shultz, SR, Wright, D, Stanwell, P. (2015). *A Systematic Video Analysis of Concussion in the National Rugby League* presented at the *American Academy of Neurology 67th Annual Meeting*, April 18- 25, 2015; Washington, DC, USA.

Gardner AJ, Stanwell P. (2013). *Preliminary cognitive and neuroimaging findings in retired professional rugby league players* presented at the *3rd Australian Neurotrauma Symposium*, 25-26 October, Hobart, TAS, Australia.

NON-PEER REVIEWED PUBLICATIONS:

Gardner A, & Stanwell P. (2012). Riskante Gehirnerschütterungen Chronisch traumatische Enzephalopathie (CTE) als Folge von Kopfverletzungen. *Medical Sports Network – Germany*, 4, 22-25.

Gardner A. (2014). Concussion & Dementia: What are the potential risks for later life cognitive and mental health issues for retired rugby league players? *Men of League Foundation Magazine*, 2, pp17-18.

STATEMENT OF CONTRIBUTION OF OTHERS

Publication 1: Gardner A, Iverson GL, Levi CR, Schofield PW, Kay-Lambkin F, Kohler RM, Stanwell P. (2015). A systematic review of concussion in rugby league. British Journal of Sports Medicine, 49(8):495-498.

I, Grant Iverson, attest that Research Higher Degree candidate Andrew Gardner contributed to the conceptualisation, database search, selection of eligible publications, the data extraction, analysis and drafting of the manuscript to the publication entitled “A systematic review of concussion in rugby league.”

Grant L. Iverson

Date: 12 June 2015

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Publication 2: Gardner A.J., Stanwell P, Levi CR, Quinn TN, Makdissi M, Shultz SR, Wright D, Iverson GL. (2015). A video analysis of concussion in the national rugby league: a preliminary study. Brain Injury. Accepted March 21, 2015; Epub ahead of print June 17.

I, Peter Stanwell, attest that Research Higher Degree candidate Andrew Gardner contributed to the conceptualisation, data collection, video analysis coding and documentation, data analysis and drafting of the manuscript to the publication entitled “A video analysis of concussion in the national rugby league: a preliminary study.”

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Publication 3: Gardner, A.J., Iverson, G.L., Stanwell, P., Moore, T., Ellis, J., Levi, C.R. (2015). A Video Analysis of the Use of the New 'Concussion Interchange Rule' in the National Rugby League During the 2014 Season. International Journal of Sports Medicine, (2015) submitted June 8.

I, Grant Iverson, attest that Research Higher Degree candidate Andrew Gardner contributed to the conceptualisation, data collection, video analysis coding and documentation, data analysis and drafting of the manuscript to the publication entitled "A Video Analysis of the Use of the New 'Concussion Interchange Rule' in the National Rugby League During the 2014 Season."

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Publication 4: Gardner, A.J., Iverson, G.L., Stanwell, P. (2014). A Systematic Review of Proton Magnetic Resonance Spectroscopy Findings in Sport-related Concussion. Journal of Neurotrauma, 31(1):1-18.

I, Grant Iverson, attest that Research Higher Degree candidate Andrew Gardner contributed to the conceptualisation, database search, selection of eligible publications, the data extraction, analysis and drafting of the manuscript to the publication entitled “A Systematic Review of Proton Magnetic Resonance Spectroscopy Findings in Sport-related Concussion.”

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Publication 5: Gardner AJ, Iverson GL, Wojtowicz M, Lin A, Levi CR, Kay-Lambkin F, Schofield PW, Zafonte, R, Shultz, S, & Stanwell P. (2015). MR Spectroscopy Findings in Retired Professional Rugby League Players. Medicine & Science in Sports & Exercise, submitted September 19.

I, Grant Iverson, attest that Research Higher Degree candidate Andrew Gardner contributed to the conceptualisation, data collection, and the drafting of the manuscript to the publication entitled “Magnetic Resonance Spectroscopy and Cognitive Findings in Retired Professional Rugby League Players.”

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