

**Academic achievement in early adolescent rugby players with multiple concussions: A retrospective analysis.**

**M.G. Kriel**

**20320213**

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**Supervisor: Dr. D.K. Kirsten**

**Co-Supervisor: Dr. D. Alexander**

**November 2012**

## Acknowledgements

Firstly I would like to give all honour and praise for this work to my Heavenly Father, the Creator and Imparter of knowledge. Lord, Your strength has been my shield, and Your grace has been my covering. May I always glorify Your name through my work.

I would also like to say thank you to my parents, Chris and Berdine de Klerk, who have never stopped believing in me. Your support, encouragement and sacrifices to make this possible have touched my heart and changed my life.

To my steadfast husband, Jacobus Kriel. I commend your patience and your guidance. Your motivation picked me up when I felt like giving up. Thank you for holding my hand during this journey. God has blessed me with your love.

To my siblings, Riana and Christiaan. Thanks for reminding me not to take life too seriously. You two colour my life brightly!

To my grandparents, who have prayed for me, called to check in on me and always showed such interest. Without you, this journey would have been lonely. Thank you for helping to make this possible.

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Finally, I dedicate this paper to each and every one of my friends and family members that have supported and prayed for me during my studies. Your encouragement and prayers have been like wind beneath me and have carried me on when the road became difficult. May God bless you, as He has blessed me through you.

## Contents

<b>Acknowledgements</b>	<b>p. ii</b>
<b>Summary</b>	<b>p. iv</b>
<b>Opsomming</b>	<b>p. ix</b>
<b>Preface</b>	<b>p. xiv</b>
<b>Letter of consent</b>	<b>p. xv</b>
<b>Certificate of language editing</b>	<b>p. xvi</b>
<b>Instructions to authors</b>	<b>p. xvii</b>
<b>Cover page of manuscript</b>	<b>p. xix</b>
<b>Abstract</b>	<b>p. xx</b>
<b>Manuscript</b>	<b>p.1</b>
<b>Method</b>	<b>p. 5</b>
<b>Research design</b>	<b>p.5</b>
<b>Participants</b>	<b>p. 5</b>
<b>Ethical considerations</b>	<b>p. 6</b>
<b>Data analysis</b>	<b>p. 6</b>
<b>Results</b>	<b>p. 7</b>
<b>Discussion</b>	<b>p. 8</b>
<b>Limitations</b>	<b>p. 10</b>
<b>Conclusion and recommendations</b>	<b>p. 10</b>
<b>Acknowledgements</b>	<b>p. 11</b>
<b>References</b>	<b>p. 12</b>
<b>Table 1:</b>	<b>p. 16</b>
<b>Table 2:</b>	<b>p. 17</b>
<b>Figure 1:</b>	<b>p. 18</b>
<b>Table 3:</b>	<b>p. 19</b>

## Summary

### **Academic achievement in early adolescent rugby players with multiple concussions: A retrospective analysis.**

#### **Keywords:**

academic functioning; brain reserve capacity; concussion; early adolescent; mild traumatic brain injury; neurocognitive development; neuropsychology; rugby union

Rugby is a popular sport in South Africa, and has been played by young boys from as early as seven years old (South African Rugby Union [SARU], 2011). Despite various physical health benefits, it carries a high risk for injury, especially head injury, and consequently has a high incidence of concussion (Alexander, 2009; Laubscher, 2006; Shuttleworth-Edwards, Smith & Radloff, 2008). It is common for 12 to 13 per cent of adolescent rugby players to report mild traumatic brain injury or concussion per season (Laubscher, 2006; Shuttleworth-Edwards et al., 2008). The true incidence is however considered to be higher, even as high as 70.4% (Shuttleworth-Edwards et al., 2008).

Concussion, otherwise known as mild traumatic brain injury (mTBI) is described as a traumatically induced alteration in mental status, or traumatically induced cerebral dysfunction (Kraus, McArthur, Silvermand & Jayaraman, 1996) which may, or may not involve loss of consciousness (Quality Standards Subcommittee, American Academy of Neurology [AAN], 1997). The nature of concussion has traditionally been considered to be transient, and symptoms are usually resolved within a few days or weeks (Kirkwood et al., 2008; Taylor et al., 2010). However, when concussions are not fully resolved prior to players returning to the game, they may be vulnerable to second impact syndrome. This syndrome causes herniation and brain oedema, which may result in death (Patel, 2005), as has been reported in South African press (Alexander, 2009; South African Press Association [SAPA], 2012).

Even without second impact syndrome, repeated concussions may render the brain neurocognitively vulnerable, leading to an array of short- and long-term cognitive symptoms

(Alexander, 2009; Shuttleworth-Edwards et al., 2008). Short-term problems include difficulties with attention, focus and concentration; following multi-step instruction, engaging in mental problem-solving; verbal expression, receiving and processing verbal and visual information; maintaining effective levels of mental and physical energy; controlling mood; suppressing impulsive behaviours; initiating and maintaining productive interpersonal relationships with peers; engaging in meaningful conversation and participating in group activities (Jantz & Coulter, 2007). Short-term cognitive impairments due to repeated concussion have also been found, and include amongst the former symptoms, also problems with delayed memory, learning, social functioning, and abstract thinking (Anderson, Brown, Newitt & Hoile, 2011; Laubscher, 2006). Long-term sequelae follow when children did not return to their baseline level of functioning after three months (Kirkwood et al., 2008; Taylor et al., 2010). Long-term sequelae include problems with memory, visuo-motor processing, executive functioning, learning and abstract thinking (Anderson, 2002; Anderson et al., 2010; Horton et al., 2010; Lezak et al., 2004; Shuttleworth-Edwards & Radloff, 2008).

As mTBI is traditionally thought to be of transient nature, researchers tend to investigate moderate to severe TBI, rather than mTBI (Alexander, 2009; Anderson et al., 2010; Patel, 2005). This could easily lead to important facts about mTBI being missed or not acknowledged. Nevertheless, recent investigations are uncovering facts about mTBI that could transform the way in which we understand mTBI, providing increasing evidence that mTBI is more serious than widely believed (Blakemore, 2012; Maxwell, 2011; Toleda et al., 2012). However, there remains a lack of research investigating mTBI from a single cause.

Considering the above information, the current study provides unique information about mTBI. It specifically investigated the long-term effects of mTBI on adolescents from a homogenous cause, which makes results more comparable. The importance of this study is highlighted in the face of evidence for the long-term effects of multiple concussions, that were sustained during school rugby, on academic achievement (Alexander, 2009; Laubscher, 2006). In the light of grey areas in existing research, the aim of this current study was to investigate whether there is a significant difference in academic achievement within and between two groups of adolescents

that had either played rugby and sustained multiple concussions, or had not played rugby nor sustained any concussions, when measured at four points in time over six years.

A retrospective data-analysis was performed on matched, controlled, prospective longitudinal data, which was obtained from a study that evaluated the impact of repeated mTBI on the cognitive and academic functioning of early adolescent rugby players over time (Alexander, 2009). This study elaborates on a subset of the previous data, adding the gr. 12 results for academic aggregate scores, to the previously reported academic dataset. Participants were selected from Alexander's study (2009), and had either played rugby and obtained two or more concussions (Rugby/Concussed (RC- group);  $n=17$ ), or did not play rugby nor sustained any concussions (Non-rugby/Non-concussed (NRC-group);  $n=13$ ).

Academic aggregate scores from baseline (gr. 7) through gr. 12 were analysed using quantitative statistical measures. A normal probability plot determined that the data was distributed normally. Descriptive statistics were reported, where after repeated measures ANOVA's were conducted to determine the statistical significance of differences in academic scores between and within the groups over time. These results indicated that the NRC-group displayed statistically significant increase in academic achievement over time ( $p = .000$ ), whereas the RC-group did not display any significant differences, despite displaying a downwards trend in achievement. The difference between the two groups was measured at its highest in gr. 12 ( $p = .003$ ), indicating that the NRC-group performed statistically significantly better than the RC-group over time. However, a Pearson's correlation test revealed that the estimated IQ (Vocabulary subscale of the WISC-III) (Wechsler, 1991) had a positive correlation on academic achievement [ $r(34) = .54, p < .05$ ]. To control for the effect that this correlation had on the academic results, an ANCOVA was conducted. This analysis indicated a statistically significant difference in academic achievement between the two groups in gr.12 ( $p = .004$ ), with a large effect size ( $d = 1.41$ ), implicating practical significance. Findings consequently confirmed our hypothesis.

The significant increase in academic achievement observed within the NRC-group over time, is consistent with what could be expected if the brain is allowed to develop normally without disruption such as mTBI (Blakemore, 2012; Horton et al., 2010). The finding that the RC group

did not display statistically significant intra-group differences in academic achievement when measured over time, but that academic achievement followed a downward trend, is difficult to substantiate in the literature. The few research studies on the effect of cumulative concussion on young athletes do not isolate academic achievement as a variable (Iverson et al., 2004; Shuttleworth-Edwards et al., 2008). Further research into intra-group differences in this specific area of enquiry and population group is therefore necessary.

Normal cognitive and brain development, maintains that the brain develops in a posterior to anterior direction, and the prefrontal regions which are vulnerable to concussion, develop last (Anderson, 2010; Blakemore, 2012; Lezak, 2004). Whereas the primary motor and sensory areas and areas for receptive and expressive language are fully developed by the age of ten years, the prefrontal brain areas that are responsible for more complex and abstract thought repertoires only start maturing in early adolescence and this development continues up to the age of 24 and even into the early 30s (Toleda et al., 2012). Injury to the developing brain at this critical stage of maturation may adversely affect the development of cognitive skills, preventing the child from acquiring the effective cognitive strategies needed for normal academic functioning and adequate academic achievement after TBI (Horton et al., 2010). However, if there is no insult to the brain, cognitive functions are expected to develop normally as a result of synaptic pruning and increased white-matter volume in the prefrontal cortex (Blakemore, 2012), making it likely that the maturation of these abilities will lead to greater cognitive and academic ability (Blakemore & Choudhury, 2006), such as seen for the NRC-group in this study.

Limitations for this study include a small sample size and the testing of only one variable. It is therefore recommended that future studies include more variables, and aim at creating a larger, randomized sample size, possibly providing a more representative pool of participants to study this phenomenon in South African context. It is also advised that future studies consider using neuropsychological measures to test cognitive functioning. As previous studies have indicated specific impairment in executive functioning after TBI, it may be worth researching the effect of concussion on executive functioning more thoroughly (Anderson, 2002; Anderson et al., 2010; Horton et al., 2010). Further it may be valuable to consider using functional MRI studies to broaden existing knowledge about the interaction between pathophysiology and cognitive

functioning This study also highly recommends that schools and rugby clubs catering for child and adolescent players reconsider the importance of implementing proper return to play protocols after players obtain concussions

## Opsomming

### **Akademiese prestasie van vroeë adolessente rugbyspelers met veelvuldige konkussies: ‘n retrospektiewe analise.**

#### **Sleuteltermes:**

akademiese prestasie; brein reserwe kapasiteit; konkussie; ligte traumatiese breinbesering, neuropsigologie; rugby; vroeë adolessensie;

Rugby is ‘n gewilde sport in Suid-Afrika en word gespeel deur jong seuns vanaf die ouderdom van sewe jaar (South African Rugby Union [SARU], 2011). Ondanks die fisiese gesondheidsvoordele wat dit inhou, beskik rugby oor ‘n hoë risiko vir besering en spesifiek ‘n hoë insidensie van hoofbesering (Alexander, 2009; Laubscher, 2006; Shuttleworth-Edwards, Smith & Radloff, 2008). Dit is algemeen dat 12 tot 13 persent van adolessente rugbyspelers ligte traumatiese breinbesering, of konkussie, per seisoen rapporteer (Laubscher, 2006; Shuttleworth-Edwards et al., 2008). Daar word egter gemeen dat die ware insidensie aansienlik hoër mag wees, selfs so hoog as 70.4% (Shuttleworth-Edwards et al., 2008).

Konkussie, ook bekend as ligte traumatiese breinbesering (TBB), word beskryf as ‘n traumaties geïnduseerde verandering in mentale status, of traumaties geïnduseerde serebrale disfunksie (Kraus, McArthur, Silvermand & Jayaraman, 1996), wat moontlike verlies aan bewussyn mag insluit, al dan nie (Quality Standards Subcommittee, American Academy of Neurology [AAN], 1997). Die aard van konkussie word as verbygaande beskou, en simptome klaar dikwels binne enkele dae of weke op (Kirkwood et al., 2008; Taylor et al., 2010). Wanneer konkussie egter nie ten volle opklaar voordat spelers terugkeer na die spel nie, is hulle kwesbaar tot tweede impaksindroom. Hierdie sindroom veroorsaak herniasie en brein-edeem, wat moontlik tot die dood mag lei (Patel, 2005). Verskeie sterftes as gevolg van tweede impaksindroom is deur Suid-Afrikaanse pers gerapporteer (Alexander, 2009; South African Press Association [SAPA], 2012).

Selfs in die afwesigheid van tweede impaksindroom, kan herhaalde konkussies (ook genoem kummulatiewe konkussies) die brein neuro-kognitief kwesbaar laat en mag dit lei tot 'n verskeidenheid van kort-, sowel as langtermyn kognitiewe simptome (Alexander, 2009; Shuttleworth-Edwards et al., 2008). Korttermyn disfunksie sluit probleme in met aandag, fokus en konsentrasie, die navolging van komplekse instruksies, verstandelike probleemoplossingsvermoëns, verbale uitdrukking, prosessering van verbale en visuele inligting, onderhouding van effektiewe vlakke van verstandelike en fisiese energie, gemoedsregulering, onderdrukking van impulsiewe gedrag, inisiëring en onderhouding van betekenisvolle interpersoonlike verhoudings met eweknieë, sowel as deelname aan produktiewe gesprekke en groepsaktiwiteite (Jantz & Coulter, 2007). Korttermyn kognitiewe inperkings as gevolg van konkussie is ook gevind en sluit, benewens die bogenoemde simptome, ook probleme in met uitgestelde geheue, leer, sosiale funksionering en abstrakte denkprosesse (Anderson, Brown, Newitt & Hoile, 2011; Laubscher, 2006). Langtermyn gevolge ontwikkel wanneer kinders nie na hulle basislyn funksionering terugkeer binne drie maande nadat hulle konkussie opgedoen het nie. Dit sluit probleme in met geheue, visueel-motoriese prosessering, uitvoerende funksionering, leer en abstrakte denkprosesse (Anderson, 2002; Anderson et al., 2010; Horton et al., 2010; Lezak et al., 2004; Shuttleworth-Edwards & Radloff, 2008).

Aangesien ligte TBB tradisioneel as minder ernstig beskou word, fokus die meeste navorsers op TBB van matige en ernstige aard, eerder as op ligte TBB (Alexander, 2009; Anderson et al., 2010; Patel, 2005). Hierdie tendens mag daartoe lei dat belangrike feite oor ligte TBB nie ontdek of erken word nie. Desnieteenstaande het onlangse ondersoek inligting oor ligte TBB ontbloot, wat die wyse waarop ons konkussie beskou mag transformeer, aangesien daar toenemend bewyse gevind word dat ligte TBB meer ernstig van aard is as wat algemeen aanvaar word (Blakemore, 2012; Maxwell, 2011; Toleda et al., 2012). Daar is egter steeds 'n tekort aan navorsing wat ligte TBB vanaf 'n enkele oorsaak ondersoek.

Met die bogenoemde inligting in ag geneem, bied die huidige studie unieke inligting oor ligte TBB. Dit ondersoek spesifiek die langtermyn effekte van ligte TBB, vanaf 'n homogene oorsaak, op adolessente, wat die resultate meer vergelykbaar maak. Die belangrikheid van hierdie studie word beklemtoon in die lig van navorsing wat bewys dat veelvuldige konkussies, wat tydens

skole-rugby opgedoen is, langtermyn effekte op akademiese prestasie het (Alexander, 2009; Laubscher, 2006). Aangesien daar gryns areas binne bestaande navorsing oor hierdie onderwerp is, is die doel van hierdie studie om te ondersoek of daar statisties beduidende verskille in akademiese prestasie is binne, sowel as tussen, twee groepe van adolessente wat of rugby gespeel het en veelvuldige konkussies opgedoen het, of wat nie rugby gespeel het of enige konkussies opgedoen het nie, wanneer hulle op vier punte oor 'n tydperk van ses jaar gemeet word.

'n Retrospektiewe data-analise is uitgevoer op ooreenstemmende, beheerde, prospektiewe, longitudinale data, wat verkry is vanuit 'n vorige studie wat die impak van herhaalde ligte TBB op die kognitiewe en akademiese funksionering van vroeë adolessente rugbyspelers ondersoek het. Hierdie studie brei uit op 'n sub-afdeling van die vorige data, deur die graad 12-resultate van deelnemers se akademiese gemiddeldes, by die vorige data te voeg. Deelnemers is vanuit Alexander (2009) se studie geselekteer, en sluit deelnemers in wat rugby gespeel het en twee of meer konkussies opgedoen het (*Rugby/Concussed* (RC-groep);  $n = 17$ ), of wat nie rugby gespeel het nie, en geen konkussie opgedoen het nie (*Non-rugby/Non-concussed* (NRC-groep);  $n = 13$ ).

Die akademiese gemiddeldes vir deelnemers is ondersoek vanaf basislyn (begin graad 7) tot graad 12, met behulp van kwantitatiewe statistiese metings. 'n Normaal-verspreidingskurwe het aangedui dat die data normaal versprei is. Beskrywende statistiek is gerapporteer, waarna herhaalde metings ANOVA op die data uitgevoer is om die statistiese beduidendheid van verskille in akademiese prestasie binne en tussen die twee groepe, oor tyd, te bepaal. Hierdie resultate dui aan dat die NRC-groep 'n statisties beduidende verbetering in akademiese prestasie oor ses jaar ( $p = .000$ ) toon. Daarteenoor het die RC-groep geen statisties beduidende verandering in akademiese prestasie oor die ses jaar tydperk getoon nie, maar 'n afwaartse tendens in akademiese prestasie is wel vir hierdie groep aangedui. Die verskil tussen die twee groepe se akademiese prestasie is op sy hoogste in graad 12 ( $p = .003$ ) gemeet, wat aandui dat die NRC-groep statisties beduidend beter as die RC-groep oor 'n tydperk gevaar het. Pearson se korrelasie het egter aangedui dat die geskatte IK-telling (aangedui deur die Vocabulary subtoets van die WISC-III), (Wechsler, 1991) 'n positiewe korrelasie toon met akademiese prestasie [ $r(34) = .54, p < .05$ ]. Om te kontroleervir die uitwerking wat hierdie korrelasie moontlik op die resultate mag hê, is 'n ANCOVA op die data uitgevoer. Hierdie analise het 'n statisties en

prakties beduidende ( $p = .004$ ) verskil van groot effek ( $d = 1.41$ ) in akademiese prestasie tussen die twee groepe in graad 12 aangedui. Gevolglik bevestig die bogenoemde resultate die hipotese van hierdie studie.

Die beduidende toename in akademiese prestasie wat observeer is binne die NRC-groep oor tyd, is in ooreenstemming met wat verwag word indien die brein normaal ontwikkel sonder enige ontwinging, soos byvoorbeeld tydens ligte TBB (Blakemore, 2012; Horton et al., 2010). Die bevindinge dat die RC-groep nie statisties beduidende intra-groepverskille in akademiese prestasie getoon het nie, word moeilik deur bestaande literatuur gestaaf. Die enkele studies wat die effek van kumulatiewe konkussies op jong atlete ondersoek het, het nie akademiese prestasie as 'n veranderlike geïsoleer nie (Iverson et al., 2004; Shuttleworth-Edwards et al., 2008). Verdere navorsing na die intra-groepverskille in hierdie spesifieke studie area, is dus noodsaaklik.

Normale kognitiewe- en breinontwikkeling dui aan dat die rigting van breinontwikkeling posterior tot anterior plaasvind, en dat die prefrontale areas, wat kwesbaar is tot konkussie, laaste ontwikkel (Anderson, 2010; Blakemore, 2012; Lezak, 2004). Terwyl die primêre motoriese en sensoriese areas, sowel as areas vir reseptiewe en ekspressiewe taal ten volle ontwikkel is teen die ouderdom van tien jaar, begin die prefrontale area eers tydens vroeë adolessensie ryp word. Hierdie area is verantwoordelik vir abstrakte en komplekse gedagte-repertoires, en ontwikkeling van hierdie area kan selfs tot in die vroeë dertigerjare strek (Toleda et al., 2012). Besering aan die brein tydens hierdie kritieke stadium van ontwikkeling en rypwording, mag nadelige gevolge vir die ontwikkeling van kognitiewe vermoëns inhou wat nodig is vir normale akademiese funksionering sowel as om voldoende akademiese prestasie te volhou, selfs na TBB (Horton et al., 2010). Indien daar egter geen besering tot die brein is gedurende hierdie tydperk nie, kan verwag word dat kognitiewe funksies normaal sal ontwikkel as gevolg van sinaptiese snoeiing en toenemende witstofvolume in die prefrontale korteks (Blakemore, 2012), wat waarskynlik daartoe sal lei dat die rypwording van hierdie vermoëns tot beter kognitiewe en akademiese vermoëns sal lei (Blakemore & Choudhury, 2006), soos wat gesien word in die resultate van die NRC-groep in hierdie studie.

Beperkinge van hierdie studie sluit in 'n klein steekproefgrootte, sowel as die meting van slegs een veranderlike. Daar word dus voorgestel dat toekomstige studies meer veranderlikes ondersoek en poog om 'n groter, lukrake steekproef te ondersoek, wat moontlik 'n meer verteenwoordigende poel van deelnemers kan betrek om hierdie fenomeen in Suid-Afrikaanse konteks te ondersoek. Verder word dit aangeraai dat toekomstige studies neuropsigologiese toetse gebruik om kognitiewe funksionering te ondersoek. Dit word spesifiek aangeraai dat uitvoerende funksionering ondersoek word, aangesien daar reeds bewyse in bestaande literatuur is dat uitvoerende funksionering as gevolg van konkussie, op die kort-termyn ingeperk mag word (Anderson, 2002; Anderson et al., 2010; Horton et al., 2010). Daar is ook aangedui dat navorsers ander hulpmiddele, soos funksionele MRI-studies, kan gebruik om 'n duideliker beeld te kry van die interaksie tussen patofisiologie en kognitiewe funksionering na konkussie. Hierdie studie raai ook skole en rugbyklubs, waarin jong kinders en adolessente speel, aan om behoorlike maatreëls in plek te stel voordat spelers terugkeer na die spel, nadat hulle konkussies opgedoen het.

## Preface

- This thesis was prepared in article format, as indicated in rule A.14.4.2 of the calendar of the North-West University, Potchefstroom Campus.
- This manuscript will be submitted to the *South African Journal of Psychology* for publication
- The manuscript was formatted according to the APA 6<sup>th</sup> edition guidelines and guidelines for authors of the *South African Journal of Psychology*. Font: New Times Roman; Font size: 12; Line spacing: 1.5.
- Attached, find the letter of consent, signed by the supervisors, authorising the author to submit this manuscript, firstly as part of requirements for the degree Magister Artium, and second to the *South African Journal of Psychology*.



NORTH-WEST UNIVERSITY  
YUNIBESITI YA BOKONE-BOPHIRIMA  
NOORDWES-UNIVERSITEIT  
POTCHEFSTROOM CAMPUS

Private Bag X6001, Potchefstroom  
South Africa 2520

**SCHOOL FOR PSYCHOSOCIAL BEHAVIOURAL  
SCIENCES: Psychology**

Tel: +27 (018) 299 1737/8  
Fax: +27 (018) 299 1730  
E-Mail doret.kirsten@nwu.ac.za

November 2012

To whom it may concern

We, the supervisors, hereby give consent that M.G. Kriel may submit the manuscript. *Academic achievement in early adolescent rugby players with multiple concussions: A retrospective analysis*, for purposes of a dissertation as part of the fulfilment of the requirements to obtain a Master's degree.

We also give permission that she may submit it to the *South African Journal of Psychology* for review, and possible publication.

Sincerely

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Dr. D. K. Kirsten  
Supervisor

---

Dr. D. Alexander  
Co-supervisor

**POTCHEFSTROOMKAMPUS**

•Privaatsak X6001 •Potchefstroom 2520 •Tel: (018) 299-1111 •Faks: (018) 299-2799 •<http://www.nwu.ac>.

**Mrs Gillian F.A. de Jager**

**Sworn & Accredited Translator  
English and Afrikaans Editor**

221 Klip Street  
MUCKLENEUK  
Pretoria 0002  
Republic of South Africa

Tel. & Fax (ask for fax line): +27 12 343-5353  
E-mail: gdejager@global.co.za

**TO WHOM IT MAY CONCERN.**

**EDITING OF ARTICLE FOR MASTER'S DEGREE IN PSYCHOLOGY.**

**TITLE: Academic achievement in early adolescent rugby players with multiple  
concussions: A retrospective analysis.**

**BY: MRS GERDA KRIEL**

I, the undersigned Mrs Gillian Frances Allen de Jager, Identity No. 421010 0038 083, declare that I am an accredited member of the South African Translators' Institute (Membership No. 1000373) with over 27 years of experience as an English editor and translator. Since retirement in November 2002, I have worked as a freelance editor and translator.

**PROFESSIONAL MEMBERSHIP**

1. SA Translators Institute, since 1990; accredited for translation from Afrikaans into English in 1996.
2. Admitted as a sworn translator in the Afrikaans and English languages, and *ex officio* commissioner of oaths in the High Court of South Africa (North Gauteng) in December 1997.

**LAST TWO CAREER POSITIONS (More details available on request)**

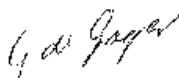
1998-01-06 – **SA RESERVE BANK**

2002-10-30 Linguist, later promoted to senior linguist, working in English and Afrikaans  
Editing confidential minutes, reports and publications, highly confidential translations for various judicial enquiries.  
Won the Departmental Award in 1999 and a Certificate of Merit in 2000 and again in 2001. Went on compulsory retirement on 31 October 2002.

95-09-01- **UNIVERSITY OF PRETORIA**

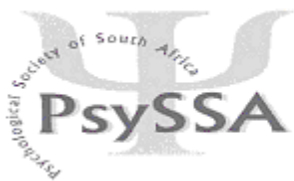
1998-05-31: Language practitioner in the Corporate Communication Division, including publications and media relations, editing of inaugural addresses, research articles, annual reports, etc.

I hereby certify that I have edited the article mentioned above as requested by the lead author, Gerda Kriel, on this the **1st** day of **November** 2012. This letter is sent as an e-mail attachment in fulfilment of the requirements for submitting the thesis for her Master's degree at the North-West University, Potchefstroom Campus, North West Province, Republic of South Africa.



G.F.A. de Jager (Mrs)

BA (Nursing), University of Pretoria; BA (Hons)(Psych.) Unisa; BA (Hons)(Eng.) *cum laude*, Unisa.



## South African Journal of Psychology

### Instructions to authors

#### Submitting a manuscript

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# MANUSCRIPT

**Academic achievement in early adolescent rugby players with multiple concussions: A retrospective analysis.**

Kriel, M. G., \*Kirsten, D. K. & Alexander, D.

Institute for Psychotherapy and Counselling, North-West University, Private Bag x6001,  
Potchefstroom, 2520

gerda.d.k@gmail.com

doret.kirsten@nwu.ac.za

debalex@sun.ac.za

### **Abstract**

The aim of this study was to determine whether there were differences in academic achievement over time within and between groups of adolescents that had either played rugby and sustained multiple concussions (RC-group;  $n = 17$ ), or had not played rugby nor sustained any concussions (NRC-group;  $n = 13$ ). A retrospective analysis of matched, controlled, prospective, longitudinal data was conducted, using data from Alexander (2009) that investigated the groups' neuropsychological performance from gr. 6 to gr. 9. The present study added their gr. 12 academic aggregate scores to the data. Participants were matched on critical attributes, such as age, socio-economic status, gender and general IQ. Data was analysed using statistical measures such as T-tests, repeated measures ANOVA, Pearson's correlation and ANCOVA measures. Intra-group results indicated a statistically significant increase in academic achievement between baseline and gr.12 for the NRC-group when measured over time ( $p = .000$ ). No statistically significant differences were found within the RC-group for academic achievement when measured over time, although their results indicated a downward trend. A highly statistically ( $p = .004$ ) and practically significant ( $d = 1.41$ ) difference in academic achievement was found between the two groups in gr. 12 indicating that the NRC-group performed significantly better than the RC-group over time. The findings imply that multiple concussions may probably restrict normal cognitive development in adolescents, limiting their abilities for optimal academic achievement. Further research which engages more participants and investigates more variables with neuropsychological testing and functional MRI-scans is recommended, as increasing evidence exists that mTBI could cause long term cognitive impairment.

#### **Key words:**

academic functioning; brain reserve capacity; concussion; early adolescent; mild traumatic brain injury; neurocognitive development; neuropsychology; rugby union

Word count = 257

Rugby (also called rugby union) is the second-most popular sport in South Africa, with a following of close to ten million (South African Rugby Union [SARU], 2011). This contact sport is played internationally in over 100 countries, by men and women, boys and girls (International Rugby Board [IRB], 2012). In South Africa the game is popular in schools where young boys, from as early as seven years old, play primarily tag-rugby (SARU, 2011). Until as recently as 2001, rugby was a compulsory sport in many South African schools (Alexander, 2009). The game consists of two teams of 15 players each, who throw, catch and kick an oval rugby ball. The body contact among players consists of tackling, scrumming, mauls and rucks (Laubscher, 2006). Rugby has various physical benefits for players, such as keeping fit, building strength and increasing overall cardiovascular health. However, as it is a contact sport, it also has a high risk of injury, especially to the head, and consequently has a high incidence of concussion (Alexander, 2009; Laubscher, 2006; Shuttleworth-Edwards, Smith, & Radloff, 2008).

The literature uses the terms concussion and mild traumatic brain injury (mTBI) interchangeably (Alexander, 2009; Laubscher, 2006), as does this study. Mild TBI is defined as a traumatically induced alteration in mental status, or traumatically induced cerebral dysfunction (Kraus, McArthur, Silverman, & Jayaraman, 1996) which may or may not involve loss of consciousness (Quality Standards Subcommittee, American Academy of Neurology [AAN], 1997). Concussion is defined as the characteristic injury of mTBI, which may also occur without a direct impact on the head, for example in whiplash injuries where the head is jerked rapidly and forcefully, causing damage to cerebral and soft tissue structures (Lezak, Howieson, & Loring, 2004).

It is common for 12 to 13 per cent of South African adolescent rugby players to report mild traumatic brain injury or concussion per season (Laubscher, 2006; Shuttleworth-Edwards et al., 2008). This figure probably does not represent the true incidence of such injuries, as later South African studies reveal that 70.4% of university rugby players have reported post-concussive symptoms in a season, even though they had not reported concussion (Shuttleworth-Edwards et al., 2008). The low reporting rates for concussion could either be due to the tendency of athletes, coaches and parents to ignore the importance of symptoms, or because players fear being dropped from their teams due to injury (Laubscher, 2006; Shuttleworth-Edwards et al., 2008). This trend is particularly dangerous because players then return to the game before they have recovered fully from the initial concussion or injury. This makes them vulnerable to second

## MULTIPLE CONCUSSION AND ACADEMIC ACHIEVEMENT

impact syndrome, which is extremely dangerous. This syndrome develops when immediate post-concussive symptoms have not yet been fully resolved before the individual is injured again by the next concussion, and is characterised by the rapid development of brain oedema and herniation, which might result in death (Patel, Shivdasani, & Baker, 2005). Various reports about adolescent rugby players dying after having a second mTBI before the initial concussion cleared up, have recently made headlines in the South African news media, and reveal an alarming state of affairs (Alexander, 2009; South African Press Association [SAPA], 2012). The risk of secondary impact syndrome in South Africa is cause for serious concern because there is no formal legislation in South Africa prohibiting players from playing rugby after suffering from concussion. SARU (2011) nonetheless endorses the IRB guidelines for concussion (IRB, 2011), which stipulate that after being concussed, players must follow a six-level graduated return-to-play protocol before playing rugby again. In terms of these guidelines, rugby players must be symptom-free for at least 24 hours after reaching each level (IRB, 2011). These guidelines are meant to govern teams at the professional and school levels (SARU, 2011), but not all of the schools adhere to them and South African learners often return to play before they have recovered fully from concussion.

One of the most prominent features of concussion is that the brain becomes dysfunctional with no apparent outward signs of physical damage (Giza & Hovda, 2004). This dysfunction is due to the pathophysiology of concussion, including diffuse axonal injury, temporarily decreased cerebral blood circulation and subsequent hypoxia (Toleda et al., 2012). These injuries do have immediate physical signs and symptoms, such as headache, dizziness, confusion, visual disturbance, double vision, mental slowing, loss of consciousness, amnesia, nausea and a marked shift in mental state (Kirkwood et al., 2008; Taylor et al., 2010). When these initial symptoms do not clear up within a few days, post-concussive syndrome may develop, even if there is no second concussion. The symptoms of post-concussive syndrome include dizziness, headache, forgetfulness, depression or anxiety, sleep disturbances, sensitivity to light and deficits in concentration (Kirkwood et al., 2008; Taylor et al., 2010), impairing a person's daily functioning. Other common cognitive difficulties that children were found to experience in the initial months following TBI, include problems with the following: attention, focus and concentration; following multi-step instructions and solving mental problems; verbal expression; receiving and processing verbal and visual information; maintaining effective levels of mental

and physical energy; controlling their moods; suppressing impulsive behaviours; initiating and maintaining productive interpersonal relationships with peers; engaging in meaningful conversation; and participating in group activities (Jantz & Coulter, 2007). Short-term cognitive impairments due to repeated concussion have also been found, and in addition to the former symptoms, also include problems with delayed memory, learning, social functioning and abstract thinking (Anderson, Brown, Newitt & Hoile, 2011; Laubscher, 2006).

Generally, children are expected to return to their baseline functioning within three months after mTBI (Kirkwood et al., 2008; Taylor et al., 2010). Nevertheless, evidence exists that a minority of children suffer from persistent post-concussive symptoms after mTBI (Taylor et al., 2010). Any sequelae or post-concussive symptoms that have not cleared up three months after injury are viewed as relatively intractable, hence constituting long-term impairment (Shuttleworth-Edwards & Radloff, 2008). Initially researchers claimed that impairment following mTBI was in most cases widespread and non-specific, signifying a mild impairment of cognitive functions (Catroppa, Anderson, Godfrey, & Rosenfeld, 2011), probably attributable to the diffuse nature of the injury (Beauchamp et al., 2011). However, this notion has recently been reconsidered, and more evidence has emerged, suggesting that mTBI may have *specific* long-term consequences such as problems with visuo-motor processing speed (Shuttleworth-Edwards & Radloff, 2008) and abstract thinking (Alexander, 2009). Other known long-term neuro-cognitive consequences include seizures, insomnia and sensory deficits such as photosensitivity, double vision and ringing in the ears (tinnitus) (Jantz & Coulter, 2007). Furthermore, there may be residual deficits in executive functioning long after the symptoms were expected to resolve, and these deficits are often severe (Horton, Soper, & Reynolds, 2010). These individuals may have trouble with purposeful, goal-directed behaviour and goal setting (Anderson, 2002; Anderson et al., 2010; Lezak et al., 2004); divided attention, sustained concentration, processing speed, task shifting, impulse inhibition such as emotional and behavioural control; error detection, working memory and social interaction (Anderson et al., 2010; Horton et al., 2010).

The debate on the long-term cognitive effects of TBI on children is far from over, especially because the findings are often contradictory, as researchers tend to focus their attention on only one aspect of TBI, such as investigating only the long-term or short-term effects, leading to an incomplete understanding of TBI. Research abounds on the short-term effects of mTBI (Horton et al., 2010). However, this is inadequate when studying mTBI in children and adolescents, as one

ought to consider the developmental aspects of their cognitive functioning. Certain functions which seem to be impaired at the time of immediate assessment after mTBI, may resolve as the brains of such children and adolescents develop new neural pathways due to plasticity (Satz, Cole, Hardy, & Rassovsky, 2010). Other functions that may initially seem unaffected directly after mTBI, may begin to show deficits after the time or developmental milestones when these functions would normally have been expected to develop, showing that children may “grow into” certain deficits in the course of time, because they develop different cognitive functions at different times (Anderson et al., 2010; Horton et al., 2010). This emphasises the need to investigate the long-term effects of mTBI too, especially in at-risk adolescent populations.

In terms of the severity of TBI, most researchers investigate moderate to severe TBI, rather than mTBI, as mTBI has traditionally been thought to be of a transient nature (Alexander, 2009; Anderson et al., 2010; Patel et al., 2005). This could easily lead to important facts about mTBI being missed or not acknowledged. Recent investigations have revealed facts about mTBI that are transforming the way we understand mTBI, providing increasing evidence that mTBI is more serious than has widely been believed (Blakemore, 2012; Maxwell, 2011; Toleda et al., 2012).

Consideration should also be given to another important aspect of the current research into mTBI, namely that the causes of mTBI may be diverse. These causes may range from falls and physical abuse, to mTBI associated with moving vehicle accidents (MVA). As a result, it is difficult to find congruent literature on the effects of mTBI when the causes are so diverse (Catroppa et al., 2011; Beauchamp et al., 2011; Rutherford, Stephens, Fernie, & Potter, 2009). Since rugby players are more prone to having repeated mTBI incidents than the players of non-contact sport, rugby players are highlighted as a population worth studying when investigating the long-term effects of mTBI, especially when researching a specific cause of mTBI (Alexander, 2009; Jantz & Coulter, 2007; Laubscher, 2006; Rutherford et al., 2009; Shuttleworth-Edwards et al., 2008).

Given the above information, the present study provides unique information about mTBI, as it specifically investigates the long-term effects of mTBI on adolescents on the basis of a homogenous cause, making the participants in the study more comparable. The importance of this study is further highlighted by evidence of the long-term effects that mTBI has on academic abilities when caused during school rugby (Alexander, 2009; Laubscher, 2006). This retrospective data analysis focused on the changes in academic aggregate scores over a period of

## MULTIPLE CONCUSSION AND ACADEMIC ACHIEVEMENT

time for a subset of adolescent participants who, had either played rugby and had more than one concussion, or who had not played rugby nor had a concussion (Alexander, 2009).

The aim of the present study was to investigate whether there was a significant difference in the academic functioning of the participants in each of these groups and between the two groups over a period of six years. It was hypothesised that there would be a change in academic achievement within and between groups when their achievement was measured over time. The null hypothesis was that there would be no difference in academic achievement within or between the groups when measured over time.

### **METHOD**

#### **Research design**

A retrospective data analysis of matched, controlled, prospective longitudinal data was used. The data were obtained from a study that evaluated the impact of repeated mild TBI on the cognitive and academic functioning of early adolescent rugby players over time (Alexander, 2009). The present study investigated these participants' academic achievement over six years, at four points in time, elaborating on a subset of the data by adding the participants' Grade 12 academic results to the previously reported data set. The Vocabulary subtest (VOC) of the third edition of the Wechsler Intelligence Scale for Children (WISC-III) (Wechsler, 1991), was used as an estimated indicator of general IQ (Strauss, Sherman, & Spreen, 2006). These results were obtained during Alexander's (2009) study. Academic aggregate scores were the dependent variable in this study, and the independent variables were rugby players' multiple concussions, and non-rugby players' non-concussions. By matching the participants for certain critical attributes, the researcher controlled any extraneous variables, ensuring the reliability of the results of the dependent variable, as the differences among the participants were minimised (Tredoux & Smith, 2006).

#### **Participants**

This study included boys who had played rugby and also sustained two or more concussions (Rugby/Concussed [RC group]; n=17), or who did not play rugby and had not sustained any concussions (Non-rugby/Non-concussed [NRC group]; n=13).

All the participants were English-speaking boys in early adolescence, who had attended a preparatory school attached to a high school catering for high functioning, high socio-economic status learners. All the boys included in the study participated in sport, but not all of them played

rugby. Their average age at the time of the data collection for this retrospective analysis was between 12.7 years at baseline, and 18.12 years in grade 12.

The participants in this study were excluded if they did not complete grade 12 at the school from which the original sample was selected. All the participants who were compromised by primary learning disorders or psychiatric disorders were excluded from the research sample, as well as the participants who had sustained moderate to severe TBI.

### **Ethical considerations**

The ethical considerations for this study are in accordance with those for the original study, conducted under the Declaration of Helsinki (Alexander, 2009) and the ethical guidelines for health research set by the Health Professions Council of South Africa (HPCSA, 2008). The Senate Research Committee of the University of the Western Cape approved the methodology and ethical aspects of the original study (Alexander, 2009). Due to the retrospective nature of this data analysis, no further ethical clearance was necessary, but attention had originally been given to obtaining the informed and written consent of the headmasters of both the preparatory and senior schools, the parents/guardians of the participants, and the participants themselves. The parents/guardians and participants were assured of the voluntary nature of participation and their freedom to withdraw from the study at any time without penalty. Anonymity and strict confidentiality were ensured.

### **Data analysis**

With the assistance of a qualified statistician, the data was analysed by means of statistical software (Statistica v.10), using quantitative statistical measures. A normal probability plot was used to determine the normal distribution of the data, and then descriptive statistics were obtained for the two groups. T-tests were done to measure differences between the two groups, using their true aggregate mean scores. Repeated-measure ANOVAs (analysis of variance) were also conducted, in order to determine the statistical significance of the differences between and within the two groups relating to their academic aggregate scores over time.

A Pearson's correlation was conducted to investigate whether age or estimated IQ (measured as VOC at baseline) had a statistically significant influence on the participants' academic results. Subsequently the correlation results indicated the need to perform an ANCOVA, in which the baseline aggregate score was controlled for the VOC, to obtain a clearer picture of the statistical significance of differences between the two groups. The aggregate score

## MULTIPLE CONCUSSION AND ACADEMIC ACHIEVEMENT

at grade 12 was controlled for both the VOC and baseline aggregate scores to determine whether there was a long-term difference between the two groups.

**RESULTS**

This retrospective data analysis focused on the changes in academic aggregate scores over time within and between the RC and NRC groups. The aim was to determine whether there were differences in academic achievement between or within these groups over a period of six years. A normal probability plot revealed that the data was distributed normally, indicating that parametric statistics could be used to analyse the data. Descriptive statistics for the groups are illustrated in Table 1.

<Table 1 approximately here>

T-test results, indicating differences between the variables of age, estimated IQ (VOC), and mean aggregate scores as measured at baseline are shown in Table 2.

<Table 2 approximately here>

Statistically significant differences were found between the two groups for both age and VOC ( $p = .025$  and  $p = .003$ ). Further analysis revealed a medium effect size ( $d = .65$ ) for the difference in age, and a large effect size ( $d = 1.0$ ) for VOC, indicating a practically significant difference in VOC between the two groups. Repeated-measure ANOVAs were subsequently taken in order to determine whether there were statistically significant differences between and within the two groups when the groups were measured over time. A Bonferroni post-hoc test correction was done to obtain the values of the reported significance. Figure 1 illustrates the results.

<Figure 1 approximately here>

A statistically significant increase ( $p = .000$ ) in academic achievement over time, when measured from baseline to grade 12, was found in the NRC group only. The RC group did not display statistically significant intra-group differences in academic achievement when measured

## MULTIPLE CONCUSSION AND ACADEMIC ACHIEVEMENT

over time, and academic achievement seemed to follow a downward trend, as there was a slight decrease in their results from baseline to grade 12.

Before controlling the data for age and VOC, a statistically significant difference was found ( $p = .0003$ ) between the two groups for their grade 12 aggregate scores, indicating that the NRC group performed significantly better than the RC group over time. To determine whether age and VOC had a statistically significant correlation with the aggregate scores, a Pearson's correlation test was conducted. The results indicated that age did not have a correlation with the aggregate scores [ $r(34) = -.17, p > .05$ ], but that VOC had a positive correlation with the aggregate scores [ $r(34) = .54, p < .05$ ]. To control for the effect that this correlation had on the aggregate scores, an ANCOVA was conducted. The results are shown in Table 3.

<Table 3 approximately here>

A non-statistically significant difference of medium effect size in aggregate scores was found ( $p = .23; d = .49$ ) between the two groups at baseline measurement. However, a statistically significant difference was found in academic achievement ( $p = .004$ ) between the two groups at grade 12, with a large effect size ( $d = 1.41$ ) implying that this had practical significance.

## DISCUSSION

The statistically and practically significant increase in academic achievement observed in the NRC group over time is consistent with what could be expected if the brain is allowed to follow a non-disrupted normal developmental process of cognitive maturation. In the normal development of the adolescent brain, the brain is expected to achieve higher-order levels of functioning and thinking (Blakemore, 2012; Horton et al., 2010), consequently empowering adolescents to perform better academically as they become more mature. The finding that the RC group did not display statistically significant intra-group differences in academic achievement when measured over time, but that academic achievement followed a downward trend, is difficult to substantiate in the literature. The few research studies on the effect of cumulative concussion on young athletes do not isolate academic achievement as a variable (Iverson, Gaetz, Lovell, & Collins, 2004; Shuttleworth-Edwards et al., 2008). Further research into intra-group differences in this specific area of enquiry and population group is therefore necessary.

## MULTIPLE CONCUSSION AND ACADEMIC ACHIEVEMENT

The fact that the NRC group performed statistically and practically significantly better than the RC group in academic achievement over a period of time, confirms the first hypothesis. The non-rugby players achieved increasingly better results in their academic performance, whereas the rugby players, exposed to years of cumulative concussions, did not. This finding is consistent with the findings of Laubscher (2006) and Shuttleworth-Edwards et al. (2008) that non-rugby players performed significantly better on academic measures when compared to rugby players. Lezak et al. (2004) asserts that intact neuropsychological functions contribute to higher levels of academic achievement. As such, the NRC group apparently retained and developed their ability to deal more successfully with more abstract and complex learning material in the course of time, as reflected in their academic achievement. This finding should also clearly be understood in terms of a developmental perspective which considers the normal process of brain development and the maturation of higher cognitive functions such as concept formation and abstract reasoning, as being reflected in improved academic achievement. The brain develops in a posterior to anterior direction, and the prefrontal regions that are vulnerable to concussion, develop last (Anderson, 2010; Blakemore, 2012; Lezak et al., 2004). Whereas the primary motor and sensory areas and areas for receptive and expressive language are fully developed by the age of ten years, the prefrontal brain areas that are responsible for more complex and abstract thought repertoires only start maturing in early adolescence and this development continues up to the age of 24 and even into the early 30s (Toleda et al., 2012). Injury to the developing brain at this critical stage of maturation may adversely affect the development of cognitive skills, preventing the child from acquiring the effective cognitive strategies needed for normal academic functioning and adequate academic achievement after TBI (Horton et al., 2010). However, if there was no insult to the brain, cognitive functions are expected to develop normally as a result of synaptic pruning and increased white-matter volume in the prefrontal cortex (Blakemore, 2012), making it likely that the maturation of these abilities will lead to greater cognitive and academic ability (Blakemore & Choudhury, 2006).

The adolescent RC group in the present study had sustained multiple concussions at what was clearly a critical stage of brain maturation and the concurrent ability to perform academically. Since the NRC group did not sustain concussions, their brains could probably develop and mature according to the normal process over the six-year period, coinciding with the

increasing inter-group difference in academic achievement observed in the two groups of participants.

When one considers the large number of pre-adolescent and adolescent boys who play rugby in South Africa and who have multiple concussions, the results of this study should be regarded as cause for concern. Schools should consider enforcing proper return-to-play protocols, and should provide proper support and treatment for rugby players after they have had concussions, even when the concussion is regarded as insignificant.

### **Limitations**

The first limitation of this study is the very small sample size. Despite being statistically usable, this sample size may not be representative of the early adolescent population in South Africa. A second limitation is that there were only a few variables to be tested. Using only the academic aggregate scores does give an indication of the academic achievement of the early adolescents participating in this study, but does not allow detailed insight into the specific strengths and weaknesses of the individual participants.

### **Conclusion and recommendations**

The results obtained from this retrospective data analysis seem to provide evidence that non-rugby players perform better than rugby players in academic achievement when measured over a six-year period. Although there is no conclusive evidence that adolescent rugby players perform statistically worse in their academic achievement when measured over a six-year period, the slight decrease in academic results, seen as a downward trend, suggests that rugby players who have sustained multiple concussions might not develop the same complex higher-order cognitive functions as their non-rugby playing, non-concussed peers, so that they do not attain the same levels of academic achievement. This finding indicates that stricter precautions might have to be taken and the IRB guidelines for concussion (IRB, 2011) might have to be implemented before rugby players return to play after having mTBI.

Recommendations for future studies researching the same theme would firstly be that more participants should be included, creating a larger and more random sample, that would provide a more representative pool of participants comparable with the South African population. Secondly, it would be preferable to consider more variables for analysis, in order to obtain a more detailed indication of the strengths and weaknesses of the participants in the different groups. It would also be advisable for future studies to consider using standardised

neuropsychological measures for assessing the participants' neuropsychological and cognitive functions, as more literature is currently available, providing evidence that concussions during adolescence cause deficits in executive functioning (Blakemore, 2012; Maxwell, 2011; Toleda et al., 2012). Furthermore, researchers may consider including the use of functional MRI-scans as a part of their research, in order to broaden existing knowledge on the long-term effect of interaction between pathophysiology and cognitive functioning, following multiple concussions. This study also strongly recommends that schools and rugby clubs catering for child and adolescent players should reconsider the importance of implementing proper return-to-play protocols after players have had concussions. Protecting the mental and cognitive health of players should be of cardinal importance to coaches and parents alike, as the detrimental effects of one or more concussions can no longer be ignored.

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## MULTIPLE CONCUSSION AND ACADEMIC ACHIEVEMENT

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## MULTIPLE CONCUSSION AND ACADEMIC ACHIEVEMENT

Table 1

*Descriptive statistics for concussed rugby players and non-concussed non-rugby players.*

	RC group (n = 17)				NRC group (n = 13)			
	Mean	SD	Range		Mean	SD	Range	
			Min	Max			Min	Max
AGG (BASE)	65.7	8.49	51.0	83.0	68.5	6.72	59.0	78.0
AGG (gr. 7)	64.3	7.24	54.0	79.0	68.3	7.36	54.0	79.0
AGG (gr. 8)	62.7	7.80	51.4	77.6	68.3	8.38	54.1	80.5
AGG (gr.9)	65.0	5.70	57.5	76.6	70.3	9.45	53.9	86.0
AGG (gr.12)	62.1	11.0	46.6	86.0	77.7	9.04	63.1	89.8

*Note:* RC-group = Rugby/ Concussed group; NRC-group = Non-rugby/ Non-concussed group; SD = Standard deviation; AGG (BASE) = Aggregate score measured at baseline; AGG = Aggregate score as measured over time.

## MULTIPLE CONCUSSION AND ACADEMIC ACHIEVEMENT

Table 2

*Differences between groups at baseline measurement for age, VOC and aggregate scores (t-tests).*

	RC group (n = 17)		NRC group (n = 13)		p	Effect size
	Mean	SD	Mean	SD		
Age	13.4	.29	13.1	.5	*.025	.65
VOC	8.9	1.9	10.9	1.5	** .003	*** 1.00
AGG (Base)	66.6	9.0	68.4	7.8	.535	.20

*Note:* RC-group = Rugby/ Concussed group; NRC-group = Non-rugby/ Non-concussed; Age = age at baseline measurement; VOC = Estimated IQ as measured by the Vocabulary subtest of the WISC-III; AGG (Base) = Aggregate score measured at baseline. \*  $p < 0.05$  = statistically significant; \*\*  $p < 0.01$  = highly statistically significant; \*\*\* Effect size =  $d > 0.8$  = Large effect size;

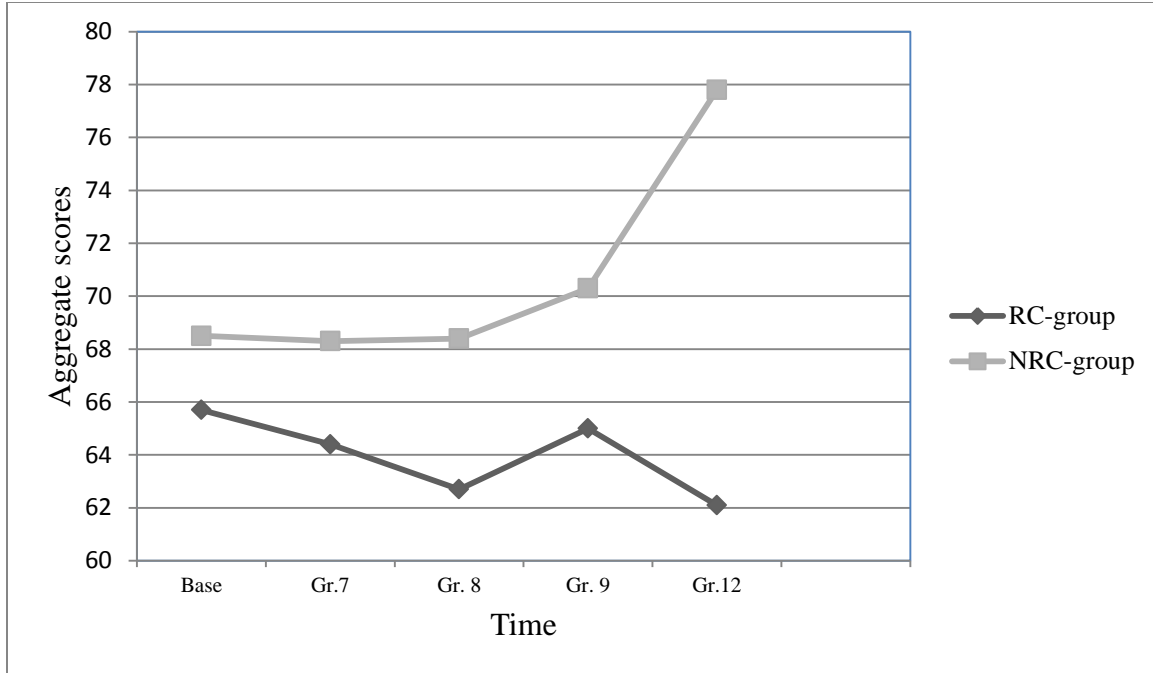


Figure 1

*Differences within and between groups' academic achievement over time (repeated measures ANOVA).*

## MULTIPLE CONCUSSION AND ACADEMIC ACHIEVEMENT

Table 3

*Between group differences for academic aggregate scores at baseline and gr. 12 (ANCOVA).*

	Adjusted means		MSE	p	Effect size
	RC group (n = 17)	NRC group (n= 13)			
Baseline	69.2	65.7	50.51	.23	.49
Gr.12	66.0	73.9	31.16	** .004	***1.41

*Note:* RC-group = Rugby/ Concussed group; NRC-group = Non-rugby/ Non-concussed group; MSE = Mean squared error; \*  $p < 0.05$  = statistically significant; \*\*  $p < 0.01$  = highly statistically significant; \*\*\* Effect size =  $d > 0.8$  = Large effect size.