CONCUSSION IN CONTACT SPORT

INVESTIGATING THE NEUROCOGNITIVE PROFILE OF AFRIKAANS ADOLESCENT RUGBY PLAYERS

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ABSTRACT

A number of computerised tests have been especially developed to facilitate the medical management of the sports-related concussion. Probably the most widely used of these programmes is the ImPACT test that was developed in the USA and that is registered with the HPCSA for use in the South African context. A recent Afrikaans version of the test served as the basis of the present study with the following objectives: (i) to collect Afrikaans ImPACT normative data on a cohort of Afrikaans first language adolescent rugby players with Model C education for comparison with existing South African English first language adolescent rugby players with Private/Model C schooling, and (ii) to investigate the pre-versus post-season ImPACT neurocognitive test profiles of this cohort of Afrikaans first language adolescent rugby players versus equivalent noncontact sports controls. The results for Part 1 of the study generally demonstrate poorer performance in respect of the Afrikaans cohort, which is understood to be the result of poorer quality of education. The results for Part 2 demonstrated failure of the rugby group to benefit from practice on the ImPACT Visual Motor Speed composite score to the same extent as the control group. It is argued that this apparent cognitive vulnerability in the rugby group is due to lowered cognitive reserve capacity in association with long term exposure to concussive and sub-concussive injury.

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CHAPTER 1. INTRODUCTION AND RATIONALE

1.1 Research objectives

This research project fell within the broader context of the collection of local normative data for rugby athletes on the Afrikaans version of the ImPACT test program, as well as an investigation into the potential for long term deleterious effects on cognition in association with participation in rugby (Shuttleworth-Edwards, Smith, & Radloff, 2008; Shuttleworth-Edwards, Whitefield, Radloff, Taylor, & Lovell, 2009; Whitefield, 2006). More specifically, the objective of the present study was twofold: First, the study set out to establish appropriate normative indications for the newly translated Afrikaans version of the ImPACT test in respect of Afrikaans first language individuals from a relatively disadvantaged (Model C) educational background; secondly the study aimed to add to existing literature on the cumulative effects of concussive and sub-concussive injuries athletes are exposed to when participating in contact sport, such as rugby, via a comparison of rugby versus noncontact controls on the Afrikaans ImPACT neurocognitive test.

1.2 Concussion in sport

Concussion is believed to be the leading injury in all contact sports (Moser, 2007). Approximately 18 % of athletes suffer concussion in any particular sporting season (McClincy, Lovell, Pardini, Collins, & Spore, 2006), with high school athletes being at the highest risk (McClincy et al., 2006; Duff, 2009). Concussion has become a serious problem in sport over the last 15 years (Ellemberg, Henry, Macciocchi, Guskiewicz, & Broglio, 2009) due to the high incidences of concussion, coupled with a lack of clarity about the long term effects of concussion (Guskiewicz et al., 2003; Guskiewicz et al., 2005; Iverson, Gaetz, Lovell, & Collins, 2004; McClincy et al., 2006; Shuttleworth-Edwards & Radloff, 2008), as well as the significant risks associated with premature return to play (Mayers, 2008; Majerske et al., 2008).

Further complicating the understanding and management of concussion is that there seems to be a very high number of athletes who never actually get diagnosed with concussion even though they experience concussive symptoms. Delaney, Lacroix, Leclerc, and Johnstone (2002) explored the incident rate of concussion in a cohort of football and soccer players at an American University and found that 23.8% of the athletes had suffered a diagnosed concussion, however, 70.4% of the same group of athletes who undertook a questionnaire had suffered at least one symptom of concussion, highlighting the difficulty of managing and diagnosing concussion in sport.

The first working definition of concussion was put forward over forty years ago by the Congress of Neurologic Surgeons (1966), who defined concussion as a clinical syndrome that is characterised by an immediate and transient alteration in mental status. In the following years, this definition was endorsed by American Medical Association as well as the International Neurotraumatology Association (Aubry et al., 2002). However, the need for a more comprehensive understanding of concussion has become particularly apparent within the sporting arena given that athletes who compete in contact sports are at serious risk of suffering from concussion (Shuttleworth-Edwards & Radloff, 2008). In response to the need to better understand the implications of concussion in sport, three international sport conferences were convened over the past decade by The International Ice Hockey Federation, the Federation Internationale de Football Association Medical Assessment and Research Centre and the International Olympic Committee Medical Commission. The first conference was in Vienna (Aubry et al., 2002), followed by Prague (McCrory et al., 2005) with the most recent being held in Zurich (McCrory et al., 2009). The main aim of the Vienna conference was to provide recommendations to improve the safety of athletes who may suffer concussive injuries in sport (Aubry et al., 2002), with the subsequent conferences being focused on revising and updating the previous conferences findings.

Culminating from the Vienna conference, and subsequently being endorsed and accepted at the Prague and Zurich concussion conferences, was the following definition of concussion (McCrory et al., 2009, pp. 76-77):

> Concussion is a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical and pathologic and biomechanical injury constructs that may be utilised in defining the nature of a concussive head injury include:
>
> 1. Concussion may be caused by either a direct blow to the head, face, neck or elsewhere on the body with an impulsive force transmitted to the head.
>
> 2. Concussion typically results in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously.
>
> 3. Concussion may result in neuropathological changes but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury.

> 4. Concussion results in a graded set of clinical symptoms that may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course; however it is important to note that in a small percentage of cases however, post-concussive symptoms may be prolonged.
>
> 5. No abnormality on standard structural neuroimaging studies is seen in concussion.

McCrory et al. (2009) highlight that the management and understanding of concussion in sport is an ongoing process and more research is still needed. It could be suggested that the one key challenge in working with concussion in sport is that no two injuries ever present in the same manner (Broglio & Puetz, 2008). Concussion injury is diffuse and often affects multiple global functions (Patel, Shivdasani, & Baker, 2005) resulting in numerous physical signs and symptoms, as well as measurable cognitive deficits (Gardner, Shores, & Batchelor, 2010). The diffuse nature of concussive injury is due to the fact that, following a blow to the body and/or head, the brain moves in a linear and/or rotational manner due to acceleration and deceleration forces. This causes significant stress to brain tissue, often resulting in the tearing of axons, possible cell death, and intracranial bleeding (Barth, Freeman, Broshek, & Varney, 2001). Whilst in some cases, symptoms of concussion may be apparent immediately following an injury, in others, symptoms may only appear the following days post injury (Ellemberg et al., 2009). Similarly, one concussed athlete may report the presence of only a single concussive symptom, while another may report multiple symptoms (Fazio, Lovell, Pardini, & Collins, 2007).

1.3 The nature of the concussive injury and post-concussive symptoms

Post-concussive signs and symptoms are commonly seen in two distinct phases, namely acute and chronic. In the acute phase, typical cognitive features of concussion are confusion, disorientation, and amnesia (Fazio et al., 2007). Loss of consciousness, also a symptom associated with the acute phase, is believed to be indicative of the most severe concussive injury, often resulting in longer recovery time. However, it has been found that some athletes who have suffered from loss of consciousness recover more quickly than some athletes who did not experience loss of consciousness (Moser, 2007), and these findings raise questions about using the presence or absence of loss of consciousness as an indicator of the severity of the injury. Furthermore, approximately 90% of concussed athletes do not experience loss of consciousness (Bailes, 2009). It has therefore been proposed that the presence of amnesia (retrograde and anterograde) is a far more accurate and clinically useful measure of the severity of concussion in sport (Cantu, 2001). Other common acute symptoms of concussion are headaches (most common), nausea, visual and balance disturbances, slurred speech, blank stare, ringing in the ears, poor balance and dizziness (Patel et al., 2005).

Following the acute phase, athletes may develop more chronic symptoms, which can be divided into three key groups (see Table 1), these being somatic, cognitive and emotional/behavioural (Duff, 2009).

Table 1. Post concussive symptoms

Somatic	Cognitive	Emotional/Behavioural
Headache	Slowed thinking, confusion	Frustration
Nausea	Slowed reaction time	Irritability
Fatigue, low energy	Impaired judgment	Restlessness
Sleep disturbances	Impaired attention	Lability
Vision change	Distractibility	Depression
Tinnitus	Impaired learning and memory	Anxiety
Dizziness, balance problems	Disorganisation	Personality change
Sensitivity to light/noise	Problem-solving difficulties	

(Duff, 2009)

Athletes can suffer from any combination of post-concussive symptoms and if concussed athletes partake in further physical activities before fully recovering, this could well exacerbate the post-concussive symptoms (Majerske et al., 2008; Mayers, 2008), and may lead to what is known as second impact syndrome (Lovell & Collins, 2002; Moser et al., 2007). Second impact syndrome is the result of the development of a brain oedema, which can lead to permanent disabilities and is sometimes associated with mortality. Second impact syndrome has mainly been reported in children and adolescent concussed athletes (Moser et al., 2007).

Studies have shown that the occurrence of headaches post-concussion are a good indicator of continued additional post-concussive difficulties, and the onset of headaches post-concussion is often correlated with memory problems and a slowed reaction response (Collins et al., 2003). Memory dysfunction and slowed reaction response are seen to be the main cognitive areas that are affected post-concussion (Patel et al., 2005). The varied manifestation of post-concussive cognitive symptoms supports the idea that concussive injury results in diffuse impairment affecting various neural brain pathways, as the speed and reaction response are seen to be a sub-cortical brain functions whereas memory functioning is primarily cortically based (Majerske et al., 2008).

It is suggested that concussive symptoms usually resolve within 3 to 7 days (Delaney et al., 2002), with most athletes recovering from concussion within 14 days (Moser et al., 2007). However, it has been shown that although an athlete may report no somatic symptoms, they may well still be suffering cognitive and emotional difficulties long after injury (Fazio et al., 2007; Moser, 2007). Studies show that some school children who suffer post-concussive symptoms go on to experience problems at school, for example, not finishing their school work and being unable to concentrate for long periods, which is often interpreted as the child being lazy or having behavioural problems (Moser, 2007). Therefore, there seems to be little clear indication regarding the duration of concussive symptoms. This is further complicated by the fact that, since concussion does not have any outward visible markers, diagnosis is heavily reliant on self reporting of symptoms by athletes, which has been shown to be an unreliable diagnostic tool on its own because athletes often under report symptoms (McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004).

There have been multiple explanations pertaining to the under reporting of concussive symptoms by athletes. Such explanations have been that athletes do not report concussive symptoms due the fear of possibly losing their position in the team and also that the culture of contact sport encourages athletes to present themselves as tough and not susceptible to injury (McCrea et al., 2004). It has also been suggested that many athletes fail to associate many of the concussive symptoms with concussion because symptoms can often be associated to other mitigating factors (McCrea et al., 2004), for example, a headache could be seen as a result of stress or dehydration. Further, talented players may be pressurised by coaches and other team members to downplay symptoms and continue playing despite injury in order to ensure team success (McCrea et al., 2004). These pressures to perform are particularly relevant in the professional sporting arena, a multi-billion dollar business that offers many athletes very lucrative financial sporting contracts (Moser, 2007).

Given the pressure that athletes experience to be injury free, and the fact that even though an athlete may report no somatic symptoms they may still be suffering cognitive and emotional difficulties, the idea that most athletes' recover from concussion in 14 days may well be misleading. This is highlighted by research findings regarding the reported recovery time of non-athletic concussed populations. A recent literature review by Belanger and Vanderploeg

(2005) reviewed the impact of concussion on a non-athlete population and found that although the majority of concussive injuries resolved within three months, a small percentage showed cognitive deficits that lingered longer than three months. A further study by Fazio et al. (2007) showed that when comparing three groups (concussed-symptomatic, concussed-asymptomatic and a control group), the symptomatic group's performance on a neuropsychological test was severely impaired in comparison to the two other groups' performance, while the asymptomatic group also performed worse in comparison to the control group. Taken together, these research findings suggest that whilst somatic symptoms may resolve within a short period of time (due to non-reporting of symptoms and/or due to recovery), cognitive deficits may continue to linger, and often go unnoticed and/or unreported in a small percentage of athletes.

1.4 Cumulative effects of concussive and sub-concussive injuries

Recently there has been strong support in the literature to suggest that athletes who have suffered more than two concussions are possibly at risk of developing subtle chronic cognitive deficits (Moser & Schatz, 2002; Moser, Schatz, & Jordaan, 2005; Wall et al., 2006). It has also been shown that athletes with a history of concussion are at a higher risk of suffering concussion again, and that their recovery time is much slower (Guskiewicz et al., 2003). Therefore, it is believed that concussive injury is cumulative and has a long-term effect on the neurocognitive functioning of athletes (Guskiewicz et al., 2003; Guskiewicz et al., 2005; Iverson et al., 2004; Shuttleworth-Edwards & Radloff, 2008).

The findings of numerous additional studies support this idea. For example, Iverson et al. (2004) found that a group of high school athletes who had a history of three or more concussions were more symptomatic and performed worse on a memory task prior to the start of a sporting season in comparison to a group of athletes with no history of concussion. Moser et al. (2005) also found that high school athletes with a history of two or more concussions performed at similar cognitive levels, in comparison to athletes who had suffered concussion in the prior week. Another study by Wall et al. (2006) examined the cognitive performance of two groups of jockeys (no history of concussion versus a history of concussion) and found that, following a three month recovery period, the concussed group still performed worse on neurocognitive testing. What was also shown was that the younger jockeys in the concussed group performed more poorly than the older jockeys in the same group. In an attempt to determine the long term effects of concussion on athletes, Guskiewicz et al. (2005) compared two groups of retired professional football players, one group with a history of three or more concussions and another group with no history of concussion. In this study, the concussed group demonstrated a higher rate of mild cognitive impairment and were at a greater risk of being diagnosed with pre-clinical memory like diseases (for example, Alzheimer's), in comparison to the non-concussed group.

What emerges clearly from this review of relevant literature is that there is a positive relationship between the number of concussive injuries sustained and the risk of cognitive deficit. However, the degree of cognitive deficit appears to differ among athletes. In order to understand the differing cognitive deficits among athletes, many researchers have focused on the severity of the injury. However subsequent results have been unable to provide consistent and sufficient explanation to the variable cognitive deficits athlete's experience (Bigler, Johnson, & Blatter, 1999). Instead, the idea of a cognitive reserve has been offered as a means of providing a working theory to explain how concussed athletes can show marked differences in recovery, and also why it is that some athletes with a history of multiple concussions appear to be at greater risk of cognitive deficits in comparison to athletes with limited or no history of concussion.

The theory of cognitive reserve (Stern, 2002) proposes that there is no direct link between the severity of an injury and the resulting cognitive deficits, but rather that the severity of subsequent cognitive deficits is dependent on the individual's cognitive reserve. It is believed that the more cognitive reserve an individual has, the more resilient they are to brain pathology (Stern, 2002). Cognitive reserve is theorised to be either active or passive in nature (Stern, 2002). A passive view is that each individual has a theoretical cognitive threshold that would be reached due to brain insult, resulting in the manifestation of cognitive deficits. Alternatively, an active model posits that the brain actively compensates for any brain insult by using as many alternative mechanisms as it has available. According to this view, cognitive deficits would manifest only once alternative mechanisms of compensation are exhausted. The theoretical construct of cognitive reserve is seen to be indirectly represented by an individual's education and/or intelligence, which is measurable in terms of IQ (Kesler, Adams, Blasey, & Bigler, 2003). Therefore, it could be suggested that the best prognostic factor following a brain insult is a greater premorbid IQ, which, in theory, would be indicative of greater cognitive reserve. This has been shown in HIV research, where individuals with lower IQ's and education/occupational achievements demonstrated greater cognitive decline, irrespective of the clinical progression of the disease, in comparison to similarly affected individuals with higher IQ’s (Basso & Bornstein, 2000). Specifically in respect of mild traumatic brain injury, a recent a study in respect of cognitive reserve and children found that children with lower cognitive ability were at higher risk of developing both acute and chronic post-concussive symptoms, in comparison to children with higher cognitive ability (Fay et al., 2010).

More specifically in relation to concussion in South African rugby, in addition to the cumulative effects of diagnosed concussive injuries, it has been suggested that rugby players who are continually exposed to high levels of contact may also suffer from sub-concussive injuries (Shuttleworth-Edwards et al., 2008; Whitefield, 2006). Sub-concussive injuries are subtle injuries sustained due to continued knocks and bumps to the body and/or head that never manifest directly in any diagnosable acute concussive symptoms (Rutherford, Stephens & Potter, 2003). It is suggested that, as is the case with concussive injury, sub-concussive injuries are also cumulative in nature, and therefore, continually lower the cognitive reserve of athletes, making them vulnerable to chronic cognitive deficits. These recent local studies serve to replicate similar international indications of effects of sub-concussive injury in soccer, ice hockey and American football (Killam, Cautin, & Santucci, 2005; Kutner, Erlanger, Tsai, Jordan, & Relkin, 2000; Rutherford et al., 2003; Rutherford, Stephens, Potter, & Fernie, 2005).

1.5 The modern approach to concussion management

The literature reviewed thus far has highlighted the significant influence that individual variables (for example, age, severity of current injury, previous history of concussive and sub-concussive injury, and cognitive reserve capacity) have on the nature, manifestation and outcome of concussive injury. In order to take these factors into account, an individualised approach to the management of concussion in sport has been proposed (McCrory et al., 2009).

This individualised approach is in contrast to past management practices of categorising concussion symptoms into different grading scales. One such grading scale that was extensively adopted was the American Academy of Neurology’s concussion grading scale (Lovell, Collins, Iverson, Johnston, & Bradley, 2004). The American Academy of Neurology’s scale has three groups, referred to as Grade 1, Grade 2 and Grade 3 concussions (Patel et al., 2005). A Grade 1 concussion is diagnosed if: (i) there is no loss of consciousness, (ii) the concussive symptoms and the athlete’s mental status returns to normal within 15 minutes and, (iii) any confusion that the athlete experiences is transient. Grade 2 concussion presents with: (i) no loss of consciousness, (ii) concussive symptoms and any mental status change lasting more than 15 minutes and, (iii) the nature of the confusion is transient. To be diagnosed with a Grade 3 concussion, loss of consciousness, for any length of time, would need to be present. Under this grading system, the grade of concussion sustained was used as the criteria for deciding when an athlete could return to play. For example, if a Grade 1 concussion was diagnosed, the athlete could return to play the same day if the concussive symptoms have subsided within 20 minutes of the injury. For a Grade 2 concussion, the athlete would need to be asymptomatic for one week before being allowed to return to play, while for a Grade 3 concussion the athlete would need to be asymptomatic for two weeks prior to returning to play. More recently, the second international conference on sport concussion proposed that it would be best to classify concussion into two groups, namely simple or complex (McCrory et al., 2005). A simple concussion was defined as any concussive injury that resolved within seven to ten days, in that the athlete would progressively become asymptomatic with no complications occurring. By means of this grading system, once the athlete was asymptomatic they could then return to playing sport. On the other hand, a complex concussion was diagnosed when an athlete continued to experience persistent concussive symptoms and complications.

Grading scales such as those described above have been heavily criticised in that they are not empirically based (i.e. arbitrary) and ignore the individual circumstances of the current injury (Duff, 2009; Shuttleworth-Edwards, 2008) as well as an athlete’s injury history. Further, it has been suggested that, since children and adolescents are still developing at a neurocognitive level, applying the same grading and management scales used for adult athletes is unsuitable given the inherent differences between the two groups (Patel et al., 2005). An additional criticism of grading scales is that they rely on the self reporting of symptoms by athletes, which has be shown to very problematic in providing a true reflection of the athletes current condition.

In response to the lack of empirical support of grading scales and the ‘one size fits all’ approach in concussion diagnosis and management, the Zurich conference abandoned the suggestions from the Prague conference of grading concussion into simple or complex, and returned to the suggestions proposed at the Vienna conference that concussion should be managed on individualised basis (McCrory et al., 2009).

1.6 Neuropsychological testing

One aspect of an individualised approach to concussion in sport involves the use of neuropsychological testing. Such testing typically takes the form of obtaining an individualised pre-season neurocognitive profile, which is then used as a standard against which to compare any further neurocognitive scores obtained during the given season, in order to assess for any cognitive change (Moser, 2007). For an athlete to be seen as concussion free or recovered, any subsequent neuropsychological test scores would need to be the same or better than the pre-season neurocognitive scores. Therefore, neuropsychological testing in the sporting arena provides a very helpful tool in that it can not only assist in detecting concussion, but also provide a valuable means to track the recovery of a concussed athlete (Moser et al., 2007). As such, neuropsychological testing is seen to be a crucial component of concussion assessment (Aubry et al., 2002; McCrory et al., 2009), and one that provides a solid empirical basis to work from when making return to play decisions (Duff, 2009). A study by Van Kampen, Lovell, Pardini, Collins, and Fu (2006) found that when diagnosing concussion by means of self reporting only, 63% of athletes were diagnosed as suffering concussion in comparison to 83% who were diagnosed by means of neuropsychological testing. What was also found was that when both self reporting of symptoms and neuropsychological testing were used together, it resulted in a 93% identification rate of concussion.

During the 1980's, Bath et al. (1989) were one of the first to investigate the use of neuropsychological testing and the assessment methods of establishing a pre-season neurocognitive profile for an athlete in order to determine the presence of concussion. They were also very interested in establishing an appropriate test battery for the assessment of concussion (Schatz & Putz, 2006). These neuropsychological test batteries were adapted from existing mainstream paper and pencil neuropsychological assessments, and instead of using extensive neuropsychological test batteries, the focus shifted to evaluating more specific areas (for example, attention, working memory and processing speed) known to be affected by concussion (Ellemberg et al., 2009). Following on the findings of Bath and colleagues, the most widely used paper and pencil neuropsychological tests that were used to detect the presence of concussion in the sporting arena were the Trail Making Test, Wisconsin Card Sorting Test, Digit Span, Symbol Digit Modalities, Grooved Peg Board and Controlled Oral Word Association tests (Ellemberg et al., 2009).

The use of these paper and pencil test within the sporting arena drew much debate and research about test reliability and validity, as well as whether or not they were sufficiently sensitive to detect the subtle effects of concussion (Ellemberg et al., 2009). For example, research findings showed that the Digit Span test had a very high reliability coefficient, but was not very sensitive to the subtle effects of concussion (Ellemberg et al., 2009). On the other hand, the Trail Making test was sensitive enough to detect subtle effects of concussion (Macciocchi, Barth, Alves, Rimel, & Jane, 1996; Matser, Kessels, Lezak, Jordan, & Troost, 1999). However, it was also shown to have a low test-retest reliability (Macciocchi, Fowler, & Ranseen, 1992), making the use of this test in the sporting arena problematic given the need to test athletes at pre-season, and then again on a regular basis if concussion was suspected. In addition to these problems, paper and pencil neuropsychological tests were also seen to be nearly impossible to administer to large groups, and the scoring and interpretation of tests is time consuming, making them very expensive to use (Ellemberg et al., 2009; Fazio et al., 2007).

1.7 Computerised neuropsychological tests

In recent years, to overcome the many shortcomings of paper and pencil neuropsychological tests, computerised neuropsychological tests have been specifically developed for the assessment of concussion in sport (Patel et al., 2005). For example, computerised tests allow for the testing of large groups, making them very cost effective to administer (Patel et al., 2005). Computerised testing also provides for a standardised test administration protocol, which increases the reliability of any neuropsychological test, and allows for a more accurate assessment (Mitrushina, Boone, Razani, & D’ Elia, 2005). Additionally, computer tests are far more sensitive in detecting cognitive changes, for example, a computer can measure the reaction time to the 0.01 of a second and are able to randomise test items and generate alternate forms of the same test, making them more reliable and valid than traditional paper and pencil tests (Lovell & Collins, 2002; McClincy et al., 2006; Patel et al., 2005). Another major advantage of computerised neuropsychological tests is that clinicians can quickly and efficiently process the results into valid and reliable clinical reports, which can then be used to make clinical decisions (Lovell & Collins, 2002; Patel et al., 2005).

A recent literature search revealed that the most commonly used computerised neuropsychological tests in respect of concussion in sport are the Automated Neuropsychological Assessment Metrics (ANAM), CogState Sport, Headminders and the

Immediate Post-concussion Assessment and Cognitive Testing (ImPACT). More specific to the South African context, ImPACT and CogState Sport appear to be the only two computerised tests that are currently in use. The CogState Sport test stimulus items consist of playing cards, which are used to measure reaction time, attention, memory (working and incidental) and spatial abilities (Schatz & Zilmer, 2003). In contrast, the ImPACT test consists of various test modules, which assess verbal and visual memory, reaction time, visual motor speed and impulse control (ImPACT Manual, 2004). Further, the ImPACT test has been translated into 13 different languages, with one of the most recent languages being Afrikaans, enhancing its applicability in the South Africa context. Currently, the ImPACT test is the only test of its kind registered with the Health Professionals Council of South Africa and the ImPACT test is approved for both clinical and research use in the South Africa context (Health Professions Council of South Africa, 2006)

1.8 Immediate Post-concussion Assessment and Cognitive Testing – ImPACT

The ImPACT test was originally developed in the USA, and has subsequently been used all over the world (ImPACT Online, 2010). The test battery takes approximately 30 minutes to complete, and consists of six different test modules (word memory, design memory, X's and O's, symbol match, colour match and three letters) which are derived from well researched traditional neuropsychological tests (ImPACT Manual, 2004). In terms of test results, ImPACT does not provide a single test score as it is proposed that such an approach would not be sensitive enough to detect concussion, since not all concussed athletes will show cognitive decline in all the test modules (ImPACT Manual, 2004). Therefore, test results take the form of five composite scores, these being Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time and Impulse Control. The ImPACT test also consists of a Symptom scale, which is currently endorsed by leading international sporting bodies (ImPACT Manual, 2004). The Symptom scale consists of 22 common concussive symptoms, and the testee is required to indicate which symptoms, if any, they have experienced over the past 72 hours. The user indicates the severity of each symptom by means of a Likert scale, from which a total Symptom score is calculated. The ImPACT test therefore incorporates both neuropsychological testing and symptom reporting, which is recognised as the most effective and accurate method of evaluating of an athlete for concussion (Van Kampen et al., 2006).

The ImPACT test has been shown to be very effective in detecting concussion and discriminating between non-concussed and concussed athletes (Fazio et al., 2007). A recent study found that ImPACT had an 89.4% positive predictive value (concussion is present and the test correlates such) while it yielded an 81.9% negative predictive value (concussion not present and the test correlates such) (Fazio et al., 2007). Further, Iverson, Lovell, and Collins (2002) showed that the ImPACT test was able to identify a group of concussed athletes who had reported concussive symptoms. It was also shown that when an inter-correlation matrix of the ImPACT scores, at pre-season and post-season, were evaluated, no significant correlations existed between the ImPACT scores and the testing dates, highlighting excellent divergent validity. The ImPACT test-rest intervals have also been shown to have a high degree of reliability in comparison to other paper and pencil tests measuring similar constructs (Iverson, Lovell, & Collins, 2003).

In addition to using ImPACT to facilitate the medical management of sports related concussion, the ImPACT test has proved to be a valuable psychometric research instrument in respect of investigating the presence and absence of practice effects in the South African context. Practice effects are improvements in performance on neuropsychological tests due to the previous exposure to the same test and not due to recovery (Duff et al., 2008). Duff et al. (2007) emphasises that instead of viewing the effects of practice as a source of error, it "has been suggested that this psychometric phenomenon [practice effects] might prove useful in predicting cognitive outcome" (p.15). To highlight the clinical importance of the presence or absence of expected practice effects in neuropsychological test results, Darby, Maruff, Collie, and McStephen (2002) administered a neuropsychological test battery repeatedly over the course of a day to a group of patients suffering from mild cognitive impairment as well matched controls. What was shown was that the control group improved on the neuropsychological tests over the course of the day, while the patients with mild cognitive impairment showed no improvement. Further, Galvin et al. (2005) showed that individuals who were progressing from mild cognitive impairment to dementia showed an absence of practice effects, even over periods of up to three years.

More specifically to local research using the ImPACT test, Whitefield (2006) provided evidence of the cumulative effects of concussive and sub-concussive injury, and the presence of lowered cognitive reserve, by means of demonstrating the failure of a clinically vulnerable group to benefit from practice to the same extent as a non clinical group. Whitefield (2006) found that a group of English first language grade 12 rugby athletes demonstrated no significant improvement on any of the ImPACT neurocognitive composites at a post-season testing interval in comparison to their pre-season test performance. In contrast, the control group in the above study demonstrated significant improvement on the ImPACT Visual Motor Speed composite at the post-season interval. In contradiction to the findings of Whitefield (2006), Shuttleworth-Edwards et al. (2008) found no improvement on any of the ImPACT neurocognitive composites for either the rugby or the control group at the post-season testing interval in comparison to their pre-season performance.

When looking more closely at these two studies, Shuttleworth-Edwards et al. (2008) administered alternate ImPACT test forms at the pre-season and post-season testing interval. Using alternate forms of a neuropsychological test significantly reduces the potential for practice effects to occur at the retest interval (Benedict & Zgaljardic, 2003), and this possibly explains why no improvement was evident in either the rugby or control groups. In contrast, in the Whitefield (2006) study, the exact same ImPACT baseline test was administered at both the pre-season and post-season testing intervals, contributing to the presence of significant improvement in the control group’s performance on the ImPACT Visual Motor Speed composite, as a result of practice. In the Whitefield (2006) study, it is possible to suggest that the rugby group’s failure to benefit from practice to the same extent as was evident for the control group represents cognitive vulnerability that may be as a result of a lowered cognitive reserve as a consequence of the cumulative effects of concussive and sub-concussive injuries.

Taking the results from the above studies as a whole, it is possible to suggest that when practice effects are expected, the absence of practice effects in neuropsychological test results may highlight possible cognitive deficits (Knight, 1992). Therefore, the absence of an expected practice effect provides valuable clinical information (Lezak, Howieson, & Loring, 2004), suggesting that practice effects might be viewed as a valuable psychometric phenomenon, instead of as a source of error. With this in mind, the methodological approach of investigating the dissociation in the amount of learning by practice between a contact and a noncontact sport group has been shown to be a powerful means of demonstrating cognitive vulnerability (i.e. lowered cognitive reserve) within a population exposed to repeated concussive and sub-concussive injuries.

Existing local research has therefore shown that ImPACT is a valid research tool for use in the investigation of possible cognitive deficits in association with participation in contact sport, such as rugby (Whitefield, 2006). In addition, ImPACT has been shown to be an invaluable resource for the management of concussion in contact sport by providing for individualised pre-season neurocognitive profiling.

1.9 Neuropsychological normative data

Although computerised neuropsychological tests, like ImPACT, provide for a very efficient and effective means to acquire pre-season baseline data against which any subsequent scores can be compared, Shuttleworth-Edwards et al. (2009) suggest that, ideally, both pre-season baseline data and appropriate normative data should be used to make clinical decisions. It is suggested that baseline data are important as they provide a highly individualised profile of pre-injury functioning (pre-season scores) to which any subsequent scores are compared in order to track recovery back to normal levels of cognitive functioning. However, if an individual’s pre-season baseline score is not a true reflection of pre-injury functioning due to possible factors like illness, fatigue and low motivation at the testing interval (which are known to affect an individual’s neuropsychological performance), any post-injury follow up testing may provide a false negative result (show no injury when one is present). Accordingly, normative data provides an alternative standard to which pre-season baseline scores can be compared with in order to highlight any significant deviation from the norm. Additionally, when no pre-season baseline data for an athlete are available, normative data provide for a reliable post-injury comparative index (Shuttleworth-Edwards et al., 2009).

1.10 Challenges of using normative data

Mitrushina et al. (2005) highlights that all identified groups have their own specific socio-cultural characteristics (for example, socio-economic status, age, gender, IQ, and level/quality of education), making normative data only clinically useful if closely matched to the identified group. The impact of socio-cultural factors on neuropsychological test performance has been well established (Shuttleworth-Edwards et al., 2004), as have the problems associated with using normative data derived from western populations in the South African context (Nel, 1999). In light of these challenges, the use of internationally developed neuropsychological instruments in the South African context raises grave concerns due to the cultural diversity and low socio-economic status of many South African citizens (Anderson, 2001).

As further emphasized by Nel (1999), quality of education, which is closely associated with socio-economic status, is an important psychometric variable that needs to be adequately accounted for when using normative data. Accordingly, local research into the local applicability of western neuropsychological tests and associated normative data has shown that individuals (regardless of race and language of origin) who have attended advantaged English medium schooling systems performed at comparable levels to western samples, while equivalent individuals (in respect of age and level of education) who have attended less privileged schooling systems, show significantly depressed performance in comparison to western samples (Shuttleworth-Edwards et al., 2004). Advantaged schools in the South African context are both Private schools and Model C schools (prior to 1994, white only schools) (Fleisch, 2007). Less advantaged schools are schools that, prior to 1994, were situated in the townships and controlled by the Department of Education. Unfortunately, these schools continue to be poorly resourced, resulting in relatively disadvantaged education compared with the former white schools, despite South Africa's new democracy post 1994.

Recent research conducted by Shuttleworth-Edwards, van der Merwe, van Tonder, and Radloff (in press), using the Wechsler Intelligence Scale for Children – IV, revealed a general trend of Private schooling English medium grade 7 learners performing better than Model C school English medium grade 7 learners, who both performed better than Model C Afrikaans medium grade 7 learners. By way of an explanation for these results, Shuttleworth-Edwards et al. (in press) suggested that Private schools are better funded than Model C schools, and are therefore in a position to offer their learners a better learning environment. With regard to the differences in test performance observed between the Model C schools, Shuttleworth-Edwards et al. (in press) suggested that these differences may have been the result of differential test administration between schools (English and Afrikaans). The Afrikaans group was administered a non-standardised Afrikaans translation of the WISC-IV, and it has been shown that direct translation of certain neuropsychological tests into other languages can cause reliability and validity concerns (Van de Vijyer, Mylonas, Pavlpoulos, & George, 2003). Additionally, it is possible that the Afrikaans learners' attitude towards neuropsychological tests may not have been the same as the English learners, who may have been more influenced by western ideas. Acculturation is an influential factor in neuropsychological test performance, and should always be taken into consideration when evaluating assessment results (Lezak et al., 2004). The results of these existing research studies show considerable differences in neuropsychological test performance as a result of socio-cultural and quality of education variables, highlighting the importance of using appropriate normative data that accurately takes these variables into account. However, only a few Afrikaans medium schools were included in the above study, highlighting sampling limitations that need to be taken into consideration before generalising these findings to the broader Afrikaans medium schooling system.

1.11 Existing local normative data for ImPACT

Given the importance of socio-cultural variables on the validity of normative data for a given population, Shuttleworth-Edwards et al. (2009) undertook a normative study to investigate the validity of the US ImPACT normative data within the South African context. The resulting normative comparison between US normative data and ImPACT neurocognitive scores derived in respect of the South African normative sample revealed closely equivalent performances between these two groups. Importantly, however, the South African normative sample consisted of English first language athletes from relatively advantaged educational backgrounds (Private and Model C schooling). As yet, there are no normative data in respect of Afrikaans first language individuals from an Afrikaans medium Model C government schools for the newly translated Afrikaans ImPACT test.

1.12 Rationale of the present study

The literature reviewed thus far has highlighted the need for a more effective approach to managing concussion in contact sport, particularly in respect of child and adolescent athletes, who are at a higher risk of concussive injury, and are also at risk of second impact syndrome. Within the sporting arena modern approach to concussion management is neuropsychological testing in order to obtain individualized pre-season neurocognitive profiles that are then used as a basis for detecting cognitive changes following injury, and monitoring subsequent recovery so as to accurately inform decision about return to play. In cases where individualized baseline profiles are either inaccurate or unavailable, demographically matched normative data provide a valuable comparative basis on which diagnoses and management recommendations can be made.

Internationally and locally, the ImPACT test has been shown to be a valuable neuropsychological instrument, both in the context of facilitating more effective clinical management of sports related concussive injury, and also within the broader context of ongoing research into the cumulative effects of concussive and sub-concussive injury associated with participation in contact sport. However, whilst ImPACT is currently used widely within the South African context, existing local normative data is thus far limited to English first language individuals from relatively advantaged educational settings. Against this background, this study sought to expand the utility of this neuropsychological instrument by undertaking research in respect of Afrikaans first language adolescents from a relatively disadvantaged educational setting.

Previous research (Fay et al., 2010; Shuttleworth-Edwards et al., in press) has: (i) demonstrated depressed WISC-IV performance in respect of Afrikaans first language individuals from an Afrikaans medium Model C government school in comparison to English first language individuals from more advantaged (Private and Model C) schooling, and (ii) has shown a relationship between brain reserve capacity and educational attainment and IQ. Based on these findings, it could be hypothesized that this cohort represents a relatively educationally vulnerable population (in terms of cognitive reserve capacity), and therefore those with exposure to repetitive brain insults in association with a game like rugby might show more pronounced cognitive lowering than a relatively more protected population with a higher level and/or quality of education.

Based on the above hypothesis, the present study had two distinct aims (Part 1 and Part 2)

Part 1: The first aim of the present study was to establish appropriate normative indications for the newly translated Afrikaans version of the ImPACT test in respect of Afrikaans first language individuals from a relatively disadvantaged (Model C) educational background. As stated previously, the only existing normative data for the ImPACT test was obtained in respect of English first language individuals from relatively advantaged educational backgrounds (Private and Model C schooling). Acquiring group specific normative data is particularly important given the influence of socio-cultural and educational variables on the performance on neuropsychological measures of cognitive ability.

Part 2: The second aim of the present study was to add to existing literature which is concerned with understanding the cumulative effects of concussive and sub-concussive events athletes are exposed to when participating in contact sport, such as rugby. This was investigated by means of comparing rugby versus a noncontact control group at both a pre-season and post-season testing intervals, on the Afrikaans ImPACT neurocognitive test. In addition, a comparison between the pre-season versus post-season testing interval performance for each group was undertaken.

CHAPTER 2. METHODOLOGY

2.1 Introduction

As outlined previously, this study encompassed two distinct aims. Part 1 of this study was aimed at establishing pre-season normative data for the five neurocognitive composite scores of the Afrikaans ImPACT test. Part 2 entailed an investigation into the presence of neurocognitive deficits due to concussive and sub-concussive injuries by means of a comparison between rugby versus controls at pre-season versus post-season intervals and by within group comparisons.

2.2 Participants

2.2.1 Initial participant groups

The participants in this study were drawn over a two year period (2009 and 2010) from two Afrikaans Model C government schools in the Eastern Cape (one school per year). A non-probability purposive sampling strategy was used to select the participants in that participation was voluntary and based on availability (Terre Blanche, Durrheim, & Painter, 2006). The rugby coaches from both schools were approached, and the research objectives were discussed. The rugby coaches assisted in identifying two distinct groups of participants, these being one group who played rugby and one control group of participants who did not engage in any form of contact sport.

2.2.2 Participation consent

The Eastern Cape Department of Education gave permission for this research to be conducted during 2009 and 2010 (Appendix 5). Written consent was also obtained from the school headmasters (Appendix 1) as well as the relevant rugby coaches (Appendix 2). In addition, all participants (Appendix 3) and their parents/guardians (Appendix 4) were required to sign an informed consent form before any data were collected. All of the informed consent forms were in Afrikaans.

2.2.3 Selection and exclusion criteria

In respect of inclusion criteria, the final participants who were included in this study were all male Afrikaans first language learners, who attended a Model C Afrikaans government school, and were between the ages of 15 and 18 years old. Exclusion criteria included a number of variables that are known to affect the performance of test takers on neuropsychological assessments (Shuttleworth-Edwards et al., 2008), as follows: (i) a history of any neurological and/or psychiatric disorders, had (ii) a concussion five months prior to the pre-season testing, (iii) a history of any severe traumatic brain injury, (iv) a history of substance abuse and/or dependence. No participants were excluded on the basis of any of the above criteria. The initial sample of participants drawn into the study consisted of 48 individuals in the rugby group, and 35 individuals in the control group.

2.3 Part 1- Normative study

2.3.1 Final groups and participants

Part 1 of this study consisted of all the rugby participants who undertook the pre-season testing, at which point the rugby participants could be considered a fundamentally non clinical population. The decision to include only rugby participants in the normative study and exclude the control participants was based on the fact that the existing local English ImPACT normative data (Shuttleworth-Edwards et al., 2009) consists of only rugby players. Therefore, in the interests of obtaining an appropriately matched Afrikaans normative comparison group, only the rugby participants were included in the normative study. The reasoning behind the assumption of the rugby participants being a non clinical population, is that: (i) these individuals complied with all the exclusion criteria listed above, and (ii) given that they had not played rugby since the end of the prior season, they would not have been exposed to repetitive head jarring or concussive events in association with the game for a period of at least five months, and therefore they would not be suffering any acute or sub-acute effects of any such injury The rugby participants were stratified into two age groups, namely 15 – 16 and 17 -18, in order to comply as clearly as possible with the existing local English normative data that are stratified in age groups of 14 – 16 and 17 – 21. The total number of participants who made up Part 1 of this study was 48 (N = 48), with 24 participants (n=24) falling in the 14 – 16 year normative group, and 24 participants (n=24) falling in the 17 – 21 year normative group.

2.4 Part 2- Concussive and sub-concussive injuries

2.4.1 Final groups and participants

From the initial sample of 48 rugby and 35 control participants, a final sample was derived for Part 2 of the study consisting of 39 rugby and 29 control participants. From the initial sample, nine participants in the rugby group and six participants in the control group were excluded for the following reasons: (i) all participants who had received a concussion between the pre-season and post-season testing intervals were excluded (rugby n = 5) as Part 2 of this study sought to establish the effects of cumulative reported and unreported concussive and sub-concussive injuries of previous rugby seasons, as well as the effects of any unreported cumulative concussive and sub-concussive injuries of the current rugby season, (ii) all participants who failed to return for the post-season testing interval were excluded (rugby n = 2; controls n = 4).

In addition, given that age, education and IQ factors can affect performance on neuropsychological tests, the rugby group and control group were compared at the pre-season interval in terms of: (i) age, (ii) years of education, and (iii) estimated level of IQ (using the Ravens Standard Progressive Matrices) in order to establish equivalence between the two groups in respect of these variables. The rugby and control groups were also compared in terms of history of concussions, with the assumption being that the rugby group would have had a greater exposure to such injury.

Initially when the two groups were compared on age, years of education and estimated level of IQ, there was no significant difference for education and IQ levels between the groups, but there was a significant difference between the two groups in terms of age (*p* = .027, rugby Mean = 16.97 versus control Mean = 17.43). Therefore, in order to establish two groups that were closely matched in respect of age as well as years of education and estimated level of IQ, the two oldest participants in the control group, and the two youngest participants in the rugby group were excluded from this study, resulting in two slightly reduced comparative groups of rugby (n = 39) and controls (n = 29) that were equivalent for age (*p* =.126), years of education (*p* =.144), and Ravens IQ Scale (*p* = .246)(Table 2). In contrast to equivalence across the comparative rugby and control groups for the three control variables of age, years of education and estimated level of IQ, in respect of previous number of concussions, a highly significant difference was in evidence in the direction of the rugby group reporting a higher number of previous concussion in comparison to the control group (*p* = .000) (Table 2).

The racial distribution of the final sample (N = 68) was predominantly made up of white Caucasian participants, with a relatively even racial distribution across the comparative rugby and control groups. Specifically, the rugby group (n = 39) consisted of 5 black, 1 coloured and 33 white participants; the control group (n = 29) consisted of 3 black, 2 coloured and 24 white participants.

Table 2. Independent t-test comparisons of rugby versus control for - age, Ravens IQ scale, years of education and number of concussions.

	Rugby		Control					
	(n = 39)		(n = 29)			*Effect size*		
	Mean	(SD)	Mean	(SD)	*t-value*	*d-value*	*95% CI*	*p-value*
Age	17.04	(0.82)	17.35	(0.83)	-1.550	-0.38	-0.86, 0.11	.126
Ravens IQ scale	44.97	(6.56)	46.76	(5.71)	-1.172	-0.29	-0.77, 0.20	.246
Years of education	10.13	(0.92)	10.45	(0.83)	-1.477	-0.36	-0.85, 0.12	.144
No. of concussions	0.87	(1.11)	0.07	(0.26)	3.830	0.94	0.43, 1.44	.000**

** $p \leq .01$

2.5 Data collection and analyses

2.5.1 Measures used

Data were collected using two psychometric instruments, namely the Ravens Standard Progressive Matrices and the ImPACT (baseline) test.

2.5.2 The Ravens Standard Progressive Matrices

The Ravens Standard Progressive Matrices test, which is seen to be the “best single measure of g available” (Kaplan & Sacuzzo, 2008, p. 325), was used as a measure of establishing equivalence between groups with regards to estimated level of IQ**.** The Ravens Standard Progressive Matrices test has been shown to be a reliable and valid measure of IQ (Gregory, 1992), and has been shown to be a relatively culture free test that has been used extensively in cross-cultural studies (Abdel-Khalek & Raven, 2006). The Ravens Standard Progressive Matrices test is a paper and pencil assessment and consists of 60 test items of increasing and varying difficulty. Testees are required to complete a pattern by means of selecting the appropriate missing piece from a group of possible answers.

2.5.3 ImPACT (Immediate Postconcussion Assessment and Cognitive Testing)

The ImPACT test has been specifically developed for the assessment of concussion in sports and, since its development, the ImPACT test has been shown to be a reliable and valid instrument for use in the sporting arena (Fazio et al., 2007). The ImPACT test is web-based, which means that all test takers are required to access the internet and take the test online. The ImPACT test consists of a demographic section, medical history section, symptom checklist, and the neurocognitive test battery, which was the focus of this study. The neurocognitive test outcome results in the production of five automatically generated composite scores that can be seen to assess two broad cognitive modalities, these being memory and attention. For the purposes of this study therefore, the tests were divided into: (i) a Memory modality made up of the ImPACT Verbal Memory and Visual Memory neurocognitive test composites and, (ii) a Attention modality made up of the ImPACT Visual Motor Speed, Reaction Time and Impulse Control neurocognitive test composites. (The outcome on the Symptom Scale was not included for analysis because the focus of the present study was restricted to an analysis of objective test outcome of the ImPACT neurocognitive parameters only).

2.6 Testing intervals and applied procedures

The administration of the neuropsychological assessments occurred at two different intervals (pre-season and post-season). The pre-season interval consisted of the administration of the Ravens Standard Progressive Matrices test as well as the ImPACT test. At the post-season interval, the exact same ImPACT (Baseline form) test was administered, in order to facilitate the investigation of the presence of practice, which has been shown to be a valuable methodological approach in previous studies (Whitefield, 2006). The same test batteries were administered to both the rugby and control groups.

2.6.1 Pre-season testing interval

The pre-season testing was conducted as soon as administratively possible at the beginning of the rugby season (March/April in both 2009 and 2010). All of the participants completed the computerised Afrikaans ImPACT test as well as the paper and pencil Ravens Standard Progressive Matrices test. Prior to undertaking the ImPACT test, the participants were given instructions on how to log onto the ImPACT website and were then instructed to follow the test instructions on the computer. On average, the ImPACT test took approximately 30 minutes to complete. On completion of the ImPACT test, the Ravens Standard Progressive Matrices test was administered. Each participant was given a protocol book, answer sheet and pencil. Test instructions were explained to the group, and an example was demonstrated. All participants completed the test within 20 minutes.

2.6.2 Post-season testing interval

The post-season testing interval was conducted towards the end of the rugby season (August in both 2009 and 2010). The exact same ImPACT test (Baseline form) that was administered at the pre-season test interval was administered again, and the same testing procedures and protocols used at the pre-season interval were repeated.

2.7 Data scoring

The Ravens Standard Progressive Matrices test was scored manually by the researcher. The generated raw scores from the Ravens Standard Progressive Matrices test were not converted into percentiles due to the fact that the raw scores were used only to compare estimated level of IQ between the rugby and control groups as a whole. In respect of the five ImPACT neurocognitive composite test scores from both the pre-season and post-season testing intervals, these were automatically generated by the ImPACT program on completion of the ImPACT test. These data were stored on the University of Pittsburgh Medical Center computer servers, and access is monitored by means of strict security protocols, with the researcher having access to this data.

In respect of Part 1 of this study, the data used for analyses consisted of the pre-season ImPACT neurocognitive composite rugby group test scores only. In respect of Part 2 of this study, the final data generated for analyses consisted of: (i) the group raw scores for the Ravens Standard Progressive Matrices test from the pre-season testing interval for both the rugby and control groups and, (ii) the ImPACT neurocognitive composite scores for both the rugby and control groups at the pre-season and post-season testing intervals.

2.8 Data analyses

All data were initially subjected to descriptive analyses, which consisted of establishing means and standard deviations for the collected data.

In respect of Part 1 of this study, the pre-season ImPACT neurocognitive composite group mean scores from the equivalent stratified rugby age groups were compared to the equivalent aged existing English normative data (Shuttleworth-Edwards et al., 2009) using one sample t-tests. Further, all the comparative results were examined by establishing effect sizes, at a Confidence Interval (CI) of 95%.

In respect of Part 2 of this study, inferential statistical analyses were run on the ImPACT neurocognitive composite group mean scores. Firstly, independent t-tests were run for the ImPACT neurocognitive composite group mean scores for the rugby versus control groups at both the pre-season and post-season testing intervals. Secondly, dependent t-tests were run for the ImPACT neurocognitive composite group mean scores for the rugby and control groups at the pre-season versus the post-season testing intervals. Again, all the comparative results were examined by establishing effect sizes, at a Confidence Interval (CI) of 95%.

2.8.1 Alpha Adjustments

Bonferroni corrections are used to minimise the potential for Type I errors (i.e., rejecting the null hypothesis when it is true) that occurs when researchers make use of several tests and/or multiple comparisons are undertaken (Nakagawa, 2004). Therefore, to guard against Type I errors in this study, the level of significance was adjusted using Bonferroni corrections based on the number of functional modalities examined (n = 2) such as has been applied in earlier research studies investigating the effects of cumulative concussion in a contact sport (Matser et al., 1999; Shuttleworth-Edwards et al., 2008).

The application of Bonferroni correction in the context of research into mild traumatic brain injury has been heavily criticized as it increases the risk of Type II error (Brandt, 2007) and therefore, making a correction for number of functions rather than number of comparisons has been the compromise solution adopted in such studies (Matser et al., 1999; Shuttleworth-Edwards et al., 2008). Applying Bonferroni corrections for two functional modalities (n = 2) in this study resulted in the 95% confidence interval level being reported using $p = .025$ and at the 99% confidence level being reported using $p = .005$.

CHAPTER 3. RESULTS

3.1 Introduction

The results from this study are reported in tabular form for both Part 1 (establishing of local Afrikaans normative indications for the five neurocognitive composite scores of the Afrikaans ImPACT test) and Part 2 (investigation into the presence of neurocognitive deficits due to concussive and sub-concussive injuries). The reported results show: (i) means, (ii) standard deviations, (iii) t-values, (iv) effect sizes (*d)*, (v) Confidence Intervals (95%), and (vi) *p*-values for each of the ImPACT neurocognitive composite scores. The reporting of the effect sizes in this study were based on Cohen's *d* statistic, with: (i) < 0.1 being very small, (ii) 0.2 being small, (iii) 0.5 being medium, (iv) 0.8 being large, and (v) >1 being very large (Tredoux & Durrheim, 2002).

The ImPACT neurocognitive composite scores are displayed under the appropriate cognitive modalities namely, Memory (consisting of Verbal Memory and Visual Memory) and Attention (consisting of Visual Motor Speed, Reaction Time and Impulse Control). In terms of the raw mean scores for the ImPACT neurocognitive composite data, a higher score is indicative of better performance except for Reaction Time and Impulse Control, where a lower score represents a better performance.

3.2 Results for Part 1 – Normative study

3.2.1 Normative data results for the age group 14 to 16 years

Table 3 compares the results for the normative ImPACT neurocognitive scores obtained during this study with existing normative data derived from English Private/Model C rugby players in the age group 14 to 16 years (Shuttleworth-Edwards et al., 2009).

In terms of the comparison between the Afrikaans Model C versus English Private/Model C normative ImPACT neurocognitive scores, a significant difference within the Memory modality for Visual Memory (*p* = .003) was revealed, in the direction of the Model C Afrikaans group performing worse. Corresponding with this significant finding was a medium effect size (*d* = -0.67) with a confidence interval that included zero. No other significant differences within either of the measured modalities were found, these being Memory (Verbal Memory *p* = .931) and Attention (Visual Motor Speed *p* = .0.58, Reaction Time *p* = .183 and Impulse Control *p* = .470).

Descriptively, what is evident is that, in respect of Verbal Memory (Mean = 81.33 versus 82.00) the two groups are closely equivalent, whereas a slightly better performance for the Afrikaans Model C group is evident on Impulse Control (Mean = 7.29 versus 8.21). However, a generally weaker performance in respect of the Model C Afrikaans group is noted for Visual Motor Speed (Mean = 31.60 versus 33.90), Reaction Time (Mean = 0.618 versus 0.600) and Visual Memory (Mean = 65.96 versus 73.30). Overall, therefore, with the exception of Verbal Memory and Impulse Control, there is a tendency for the 14 – 16 year old Afrikaans speaking participants tested on the Afrikaans version of the ImPACT test to perform more poorly than the age-equivalent English speaking participants tested on the English version of the ImPACT test.

Table 3. Part 1 – Normative comparison for South African Model C Afrikaans versus South African English Private/ Model C - Rugby age 14 – 16 years

	Normative Data South African - Model C Afrikaans first language (n = 24)		Normative Data # South African – Private / Model C English first language (n = 997)			*Effect size*		
Age group 14 – 16 years	Mean	(SD)	Mean	(SD)	t-value	d-value	95% CI	p-value
Memory								
Verbal Memory	81.33	9.33	82.00	9.90	-0.088	-0.02	-0.42, 0.38	.931
Visual Memory	65.96	10.92	73.30	13.40	-3.293	-0.67	-1.11, -0.22	.003**
Attention								
Visual Motor Speed	31.60	5.65	33.90	7.80	-1.997	-0.41	-0.82, -0.01	.058
Reaction Time	0.618	0.064	0.60	0.08	1.374	0.28	0.13, 0.69	.183
Impulse Control	7.29	5.39	8.10	5.80	-0.735	-0.15	-0.55, 0.25	.470

** p < .01, two-tailed with Bonferroni's adjustment
# Normative data derived from Shuttleworth-Edwards et al. (2009)

3.2.2 Normative data results for the age group 17 to 21 years

Table 4 compares the results for the normative ImPACT neurocognitive scores obtained during this study with existing normative data derived from English Private/Model C rugby players in the age group 17 to 21 years (Shuttleworth-Edwards et al., 2009).

In terms of the comparison between the Afrikaans Model C versus English Private/Model C normative ImPACT neurocognitive scores, no significant differences within the Memory modality (Verbal Memory *p* = .974 and Visual Memory *p* = .082) were found. In respect of the Attention modality, a significant difference for Reaction Time (*p* = .000) was found, with the Model C Afrikaans group being slower. This was accompanied by a medium effect size (*d* = 0.52) and a confidence interval which excluded zero, highlighting clinical significance. In respect of the other two ImPACT composite scores in the Attention modality, no significant differences were found for either Visual Motor Speed (*p* = .070) or Impulse Control (*p* = .503). Descriptively, what is evident is a worse performance for the Afrikaans Model C group on Visual Memory (Mean = 71.17 versus 76.00), Visual Motor Speed (Mean = 34.83 versus 38.10) and Impulse Control (Mean = 8.00 versus 6.90), with a closely matched performance between the groups on Verbal Memory (Mean = 84.17 versus 84.10). Overall, therefore, as with the younger 14-16 year old age group, with the exception of Verbal Memory, there is a tendency for the Afrikaans speaking 17- 21 year old participants tested on the Afrikaans version of the ImPACT test to perform more poorly than the age-equivalent English speaking participants tested on the English version of the ImPACT test.

Table 4. Part 1 – Normative comparison for South African Model C Afrikaans versus South African English Private/ Model C - Rugby age 17 – 21 years

Age group 17 – 21 years	Normative Data South African - Model C Afrikaans first language (n = 24)		Normative Data # South African – Private / Model C English first language (n = 319)			*Effect size*		
	Mean	(SD)	Mean	(SD)	t-value	d-value	95% CI	p-value
Memory								
Verbal Memory	84.17	9.87	84.10	10.20	0.033	0.01	-0.39, 0.41	.974
Visual Memory	71.17	13.02	76.00	13.00	-1.819	-0.37	-0.78, 0.05	.082
Attention								
Visual Motor Speed	34.83	8.43	38.10	7.30	-1.899	-0.39	-0.80, 0.03	.070
Reaction Time	0.599	0.055	0.57	0.07	2.570	0.52	0.09, 0.95	.017*
Impulse Control	8.00	7.92	6.90	4.20	0.680	0.14	-0.27, 0.54	.503

* p < .025, two-tailed with Bonferroni’s adjustment
# Normative data derived from Shuttleworth-Edwards et al. (2009)

3.3 Results for Part 2 – Neurocognitive profile comparisons

3.3.1 Independent t-test results for pre-season and post-season testing intervals

Rugby versus controls at the pre-season testing interval

The independent t-test analyses for rugby versus controls at the pre-season testing interval (Table 5) revealed no significant differences within either of the measured modalities, these being Memory (Verbal Memory *p* = .989 and Visual Memory *p* = .525) and Attention (Visual Motor Speed *p* = .645, Reaction Time *p* = .676 and Impulse Control *p* = .850). Descriptively, the two groups were closely matched on all of the ImPACT neurocognitive composite scores, these being Verbal Memory (Mean = 84.18 versus 84.21), Visual Memory (Mean = 71.03 versus 72.69), Visual Motor Speed (Mean = 34.18 versus 33.44), Reaction Time (Mean = 0.606 versus 0.600) and Impulse Control (Mean = 6.95 versus 6.69) for rugby and controls respectively.

Table 5. Part 2 - Independent neurocognitive comparisons of rugby versus controls at the pre-season testing interval

	Rugby Pre-season (n = 39)		Controls Pre-season (n = 29)			Effect size		
	Mean	(SD)	Mean	(SD)	*t-value*	*d-value*	*95% CI*	*p-value*
Memory								
Verbal Memory	84.18	8.65	84.21	7.26	-0.014	-0.00	-0.48, 0.48	.989
Visual Memory	71.03	10.85	72.69	10.28	-0.639	-0.16	-0.64, 0.33	.525
Attention								
Visual Motor Speed	34.18	6.99	33.44	5.87	0.463	0.11	-0.37, 0.59	.645
Reaction Time	0.606	0.064	0.600	0.063	0.419	0.10	-0.38, 0.58	.676
Impulse Control	6.95	4.95	6.69	6.33	0.189	0.05	-0.43, 0.53	.850

Rugby versus controls at post-season testing interval

The independent t-test analyses for rugby versus controls at the post-season testing interval (Table 6) revealed no significant differences within either of the measured modalities, these being Memory (Verbal Memory *p* = .628 and Visual Memory *p* = .330) and Attention (Visual Motor Speed *p* = .741, Reaction Time *p* = .078 and Impulse Control *p* = .615). Descriptively, however, the results for Reaction Time (Mean = 0.623 versus 0.593) show a trend in the direction of the rugby group getting slower than controls (*p* = .078). In terms of the other ImPACT neurocognitive composite scores, these being Verbal Memory (Mean = 83.82 versus 82.69), Visual Memory (Mean = 74.44 versus 71.52), Visual Motor Speed (Mean = 36.05 versus 35.55) and Impulse Control (Mean = 6.38 versus 6.97) for rugby and controls respectively, a varied performance was evident with no consistent trends, or results approaching significance.

Table 6. Part 2 - Independent neurocognitive comparisons of rugby versus controls at the post-season testing interval

	Rugby Post-season (n = 39)		Controls Post-season (n = 29)			*Effect size*		
	Mean	(SD)	Mean	(SD)	*t-value*	*d-value*	*95% CI*	*p-value*
Memory								
Verbal Memory	83.82	9.20	82.69	9.81	0.487	0.12	-0.36, 0.60	.628
Visual Memory	74.44	14.25	71.52	10.28	0.981	0.23	-0.25, 0.71	.330
Attention								
Visual Motor Speed	36.05	6.66	35.55	5.54	0.332	0.08	-0.40, 0.56	.741
Reaction Time	0.623	0.083	0.593	0.047	1.788	0.44	-0.05, 0.92	.078
Impulse Control	6.38	5.04	6.97	4.17	-0.505	-0.13	-0.61, 0.36	.615

3.3.2 Dependent t-test results for rugby and controls at pre-season versus post-season testing intervals

Rugby pre-season versus post-season testing interval

The dependent t-test analyses for rugby at the pre-season versus post-season testing interval (Table 7) revealed no significant differences within either of the measured modalities, these being Memory (Verbal Memory *p* = .819 and Visual Memory *p* = .116) and Attention (Visual Motor Speed *p* = .074, Reaction Time *p* = .121 and Impulse Control *p* = .547). Descriptively, the results for Visual Motor Speed (Mean = 34.18 versus 36.05) show a markedly better performance at the post-season interval although failing to reach significance (*p* = .074), and an effect size (*d* = -0.30) with a confidence interval that included zero, therefore implicating an effect of minimal clinical significance. In terms of the other ImPACT neurocognitive composite scores, these being Verbal Memory (Mean = 84.18 versus 83.82), Visual Memory (Mean = 71.03 versus 74.44), Reaction Time (Mean = 0.606 versus 0.623) and Impulse Control (Mean = 6.95 versus 6.38), no identifiable trend is evident.

Table 7. Part 2 – Within group neurocognitive comparisons of rugby at the pre-season versus post-season testing interval

	Rugby Pre-season (n = 39)		Rugby Post-season (n = 39)			*Effect size*		
	Mean	(SD)	Mean	(SD)	*t-value*	*d-value*	*95% CI*	*p-value*
Memory								
Verbal Memory	84.18	8.65	83.82	9.20	0.231	0.04	-0.28, 0.35	.819
Visual Memory	71.03	10.85	74.44	14.25	-1.608	-0.26	-0.58, 0.06	.116
Attention								
Visual Motor Speed	34.18	6.99	36.05	6.66	-1.840	-0.30	-0.61, 0.03	.074
Reaction Time	0.606	0.064	0.623	0.083	-1.585	-0.25	-0.57, 0.07	.121
Impulse Control	6.95	4.95	6.38	5.04	0.608	0.10	-0.22, 0.41	.547

Controls pre-season versus post-season testing interval

The dependent t-test analyses for controls at the pre-season versus post-season testing interval (Table 8) revealed a highly significant difference in the direction of better performance at the post-season testing interval, within the Attention modality for Visual Motor Speed (p = .000). Corresponding with this significant finding was a medium to large effect size (d = -0.79), with a confidence interval which excluded zero, suggesting a clinically relevant effect. In terms of the other ImPACT neurocognitive composite scores in the Attention (Reaction Time p = .611 and Impulse Control p = .840) and Memory (Verbal Memory p = .449 and Visual Memory p = .559) modalities, no significant differences were found. Descriptively, there is no trend evident between the pre-season and post-season for the ImPACT neurocognitive composite scores for Verbal Memory (Mean = 84.21 versus 82.69), Visual Memory (Mean = 72.69 versus 71.52), Reaction Time (Mean = 0.600 versus 0.593) and Impulse Control (Mean = 6.69 versus 6.97).

Table 8. Part 2 – Within group neurocognitive comparisons of controls at the pre-season versus post-season testing interval

	Controls Pre-season (n = 29)		Controls Post-season (n = 29)			*Effect size*		
	Mean	(SD)	Mean	(SD)	*t-value*	*d-value*	*95% CI*	*p-value*
Memory								
Verbal Memory	84.21	7.26	82.69	9.81	0.768	0.14	-0.23, 0.51	.449
Visual Memory	72.69	10.28	71.52	10.28	0.592	0.11	-0.26, 0.47	.559
Attention								
Visual Motor Speed	33.44	5.87	35.55	5.54	-4.249	-0.79	-1.20, -0.37	.000**
Reaction Time	0.600	0.063	0.593	0.047	0.515	0.10	-0.27, 0.46	.611
Impulse Control	6.69	6.33	6.97	4.17	-0.204	-0.04	-0.40, 0.33	.840

** $p < .01$, two-tailed with Bonferroni's adjustment

CHAPTER 4. DISCUSSION

4.1 Introduction

This study fell within the broader context of the modern approach to concussion management in the sporting arena, which involves an individualised approach that makes use of sensitive computerised neuropsychological tests, of which ImPACT is one of the most widely used. Within in the South African context, ImPACT has been researched in respect of English first language populations from relatively advantaged educational settings (Private and Model C) and normative data are available for this cohort (Shuttleworth-Edwards et al., 2009). As of yet, there are no normative data for the newly translated Afrikaans version of the ImPACT test. In addition, no local research has been done in respect of the cumulative effects of concussive and sub-concussive injury with individuals from relatively disadvantaged schooling (Model C only). Accordingly, this study had two distinct aims (Part 1 and Part 2). Part 1of this study sought to collect appropriate normative data for the newly translated Afrikaans version of the ImPACT test in respect of Afrikaans first language individuals from a relatively disadvantaged (Model C) educational background. Part 2 of this study aimed to investigate the cumulative effects of concussive and sub-concussive injuries that adolescent rugby players are exposed to as a result of their participation in contact sport. This was investigated by means of a pre-season and post-season comparison of rugby versus noncontact controls on the Afrikaans ImPACT neurocognitive test.

4.2 Part 1 – Normative study

The ImPACT normative data collected in the present study was derived in respect of Afrikaans first language participants from a Model C schooling system. These data were collected over a two year period (2009 and 2010) and stratified into two different age group categories, namely 14 to 16 years, and 17 to 21 years. These data were compared to existing age equivalent local ImPACT normative data, derived in respect of English first language athletes from both English Private and Model C schooling backgrounds (Shuttleworth-Edwards et al., 2009). In light of prior local research demonstrating the existence of a neuropsychological test performance continuum in the direction of a better performance for individuals with Private schooling in comparison to Model C schooling, and providing support for a further possible performance continuum even within the Model C schooling system (Shuttleworth-Edwards et al., in press), it was envisioned that the collected Afrikaans

ImPACT normative data would be depressed in comparison to the existing English ImPACT normative data.

Within the 14 to 16 year age group, statistical comparisons between the Afrikaans ImPACT normative data versus the existing South African English Private/Model C ImPACT normative data revealed a general trend in the direction of poorer performance for the Afrikaans Model C group in comparison to existing norms. More specifically, Visual Memory was significantly depressed ($p = .003$), while poorer performance for the Visual Motor Speed approached significance ($p = .058$). In addition, a comparison of Reaction Time composite mean scores showed a slower performance for the Afrikaans Model C group when compared to the existing South African English group. Composite scores for Verbal Memory and Impulse Control were closely equivalent for both groups.

Similarly, in respect of the 17 to 21 year age group, statistical comparisons against the existing South African English Private/Model C ImPACT normative data revealed a general trend of poorer performance for the Afrikaans Model C group. More specifically, a significant difference was found on Reaction Time ($p = .017$) in the direction of the Afrikaans Model C group's performance being slower. Descriptively, there is a clear picture in evidence of poorer performance in respect of the Afrikaans Model C group's performance on the ImPACT test composites for Visual Memory, Visual Motor Speed and Impulse control. However, in respect of the Verbal Memory composite normative comparison, a similar performance between the two groups was found.

Therefore, when comparing the Afrikaans Model C ImPACT normative data with existing English Private/Model C ImPACT normative data for both age groups (14 to 16 and 17 to 21), a general trend of depressed performance emerges in respect of the Afrikaans Model C group. This depressed performance was expected given the importance of the variable of quality of education on the performance of individuals on neuropsychological tests. However, the finding of close equivalence between the Afrikaans Model C and the existing English Private/Model C ImPACT normative data, for both age groups (14 to 16 and 17 to 21 years) on the ImPACT Verbal Memory composite, was unexpected.

One possible explanation for a similar performance on the ImPACT Verbal Memory composite is that, since the Afrikaans ImPACT test is a direct translation of the English version, it is possible that the Afrikaans ImPACT test's Verbal Memory module is not of equivalent difficulty to the original English ImPACT Verbal Memory module. Van de Vijyer et al. (2003) suggest that when directly translating neuropsychological test items into different languages, the verbal module is the most susceptible to language effects, in terms of not being a true reflection of the pre-translated verbal module test items. This often due to the fact that, when translating test modules that are reliant on verbal test items, it is sometimes very difficult to capture the targeted group’s equivalent local dialect (Mitrushina et al., 2005). The test-item differences between the Verbal Memory module and the other ImPACT neurocognitive modules, those being Visual Memory, Visual Motor Speed, Reaction Time and Impulse Control, are that the latter modules are generally more symbolic in nature (ImPACT Manual, 2004), and as such, did not require a direct translation, possibly avoiding potential differences in item difficulty that may result from translation between the English and Afrikaans. Therefore, when the ImPACT test was translated from English to Afrikaans, an equivalently difficult Afrikaans Verbal Memory module may not have been reproduced, thereby contributing to unexpected similar scores for the Afrikaans group.

The findings in the present Part 1 normative study provide additional support regarding the importance of quality of education as a critical variable that influences an individual’s performance on neuropsychological tests. This has important clinical implications for the use of neuropsychological tests to manage concussion in the South African context. As highlighted earlier, the use of normative data forms part of an individualised approach to the management of concussion in sport in instances where pre-season baseline profiles are not seen to be a true reflection of an athlete’s current cognitive function, or in instances where a pre-season baseline profile of the athlete has not been obtained. In these instances, normative data provides for a very reliable demographic comparative. Given the vast discrepancies in the quality of the South African schooling systems (Shuttleworth-Edwards et al., in press), acquiring the appropriate normative data may be a very challenging, but a necessary task.

In addition to quality of education being an influential variable in its own right**,** Nel (1999) highlights that quality of education has a direct bearing on the socio-economic status of individuals, with wealthier individuals affording higher qualities of education. This has important clinical bearing in the management of concussion with less privileged groups, as research has shown that socio-economic status, academic functioning and intelligence are seen to be good indicators of cognitive reserve, with higher academic functioning and intelligence being linked to higher cognitive reserve, which in turn afford individuals a greater resilience to withstand neurological insults, such as concussion (Fay et al., 2010). Taking into account the possible link between cognitive reserve and quality of education, the present study, by means of a second aim (Part 2), sought to investigate the effects of concussive and sub-concussive events on an Afrikaans speaking rugby group, from a Model C schooling system.

4.3 Part 2 – Neurocognitive profile comparisons

Part 2 of this study consisted of a comparison between two groups (rugby and noncontact control) at a pre-season and post-season testing interval on the five ImPACT neurocognitive composites. This comparison was directed at investigating whether participating in contact sport, such as rugby, could lead to cognitive vulnerability as a result of the cumulative effects of concussive and sub-concussive injuries. In order that any findings of cognitive vulnerability in respect of the rugby group could, with a greater degree of certainty, be attributed to their participation in contact sport, the two groups (rugby and noncontact control) were equally matched on the factors of age, education level and estimated level of IQ ($p = > 0.05$ in all instances), all of which are known to affect neuropsychological test performance.

The two groups did, however, differ in respect of previous concussive injury. A comparison between the rugby and control groups revealed a significant difference, with an accompanying large effect size, in the direction of the rugby group reporting more concussions (rugby Mean = 0.87 versus control Mean = 0.07; $p = .000$, $d = 0.94$). This difference would be expected given the rugby group's participation in contact sport, an arena in which, on average, 18% of athletes are diagnosed as suffering from either single or multiple concussions over any particular season of contact sport (McClincy et al., 2006). In addition to a significantly higher incidence of concussion, it is likely that the rugby group would have also been exposed to a higher incidence of sub-concussive injuries, which are subtle injuries to the brain sustained as a result of continued knocks and bumps to the body and/or head, that never manifest directly in any diagnosable acute concussive symptoms (Rutherford et al., 2003).

With regards to results of this study, pre-season comparisons between the rugby and control groups on the ImPACT neurocognitive composites revealed no significant differences ($p = > 0.05$ with Bonferroni's adjustment, in all instances). Descriptively, at the pre-season testing interval, the rugby and control groups were evenly matched across all of the ImPACT neurocognitive composites. This finding is in contrast to that of Shuttleworth-Edwards and Radloff (2008), who found that a group of rugby players performed significantly worse on traditional neuropsychological measures of processing speed (Digit Symbol Substitution and Trail Making A and B), in comparison to matched control group at a pre-season testing interval. However, key differences between the above study and the present study are in respect of history of concussive injury and average age.

In the Shuttleworth-Edwards and Radloff (2008) study, the average age (rugby Mean = 19.76 and control Mean = 20.49) of the participants was higher than the average age of the participants in the present study (rugby Mean = 17.04 and control Mean = 17.35), with the older rugby group reporting a significantly higher percentage of two or more concussions, whereas in the present study, the rugby group reported a history of less than one concussion. Generally, older contact athletes report a higher history of concussive injury, possibly as a result a longer career of contact sport (Rutherford et al., 2003). A study by Gardner et al. (2010) provides additional support for the idea that those rugby athletes with a history of more than two concussions demonstrate significant cognitive deficits in comparison to rugby athletes with a history of less than one concussion. This highlights the fact that the longer an athlete participates in contact sport, the higher the incidence of concussion, and therefore, differences in pre-season results between the present study and those previous can be attributed to differences in the incidence of concussion as a result of fewer years of participation in contact sport.

Further, in respect of the present study, pre-season comparison findings of no significant differences between the rugby and control groups might also be due to the fact that the rugby group had not participated in any contact sport in the five months prior to testing, and as such had not been exposed to any concussive and sub-concussive injury since the previous year's rugby season. Therefore, at the pre-season testing interval, it appears that the rugby group in the present study is a group that is not showing clinically relevant decline in association with exposure to concussive injury, and therefore on this basis, might be considered a 'non clinical' group.

When looking at the post-season comparison between the rugby and control groups on the ImPACT neurocognitive composites, whilst no significant differences were found (p = > 0.05 with Bonferroni's adjustment, in all instances), results show that the rugby group's performance is markedly slower in comparison to the control group, even though they demonstrated similar neurocognitive performance at the pre-season testing interval. This is evident on the independent t-test comparison between the rugby and control group for the

Reaction Time composite, which yielded a difference that was approaching significance in the direction of the rugby group being slower than the control group (*p* = .078), and which was accompanied with a medium effect size (*d* = 0.44). Reaction time is seen to be one of the most common cognitive deficits individuals suffer following a mild traumatic brain injury (Lezak et al., 2004) and, although the post-season comparison for the Reaction Time composite is not significant, slowed performance does point to possible cognitive compromise in the rugby group at the post-season testing interval.

Examining the dependent (within-group) comparisons of the rugby and control groups between the pre-season versus post-season testing intervals provides further support for cognitive vulnerability in the rugby group, particularly in respect of findings on the ImPACT Visual Motor Speed Composite. Relative to their pre-season performance, the control group improved significantly at the post-season testing interval on the Visual Motor Speed composite (*p* = .000). This was accompanied by a medium to large effect size (*d* = -0.79) that excludes zero, indicating clinical significance. In contrast, no significant improvement was evident in respect of the rugby group. While the rugby group does perform better at the post-season testing interval on the Visual Motor Speed composite, this improvement is only approaching significance (*p* = .074), and is accompanied by a small effect size (*d* = -0.30).

This finding of significant improvement on the ImPACT Visual Motor Speed composite for a control group, which was not evident in respect of a comparatively matched rugby group, was also found in a study by Whitefield (2006) (refer Chapter 1, pp. 13-14). Given that the exact same ImPACT baseline test was administered at both the pre-season and post-season testing intervals in the Whitefield (2006) and the present study, and in addition, given that the ImPACT processing speed composite has been shown to be the most susceptible to practice effects (Iverson et al., 2003), these findings of significant improvement on the ImPACT Visual Motor Speed composite for the control group in both the Whitefield (2006) and the present study can reasonably be attributed to practice effects.

What is clear then in both the Whitefield (2006) and the present study is that the control groups were able to benefit significantly from practice in respect of the ImPACT Visual Motor Speed composite, and that the rugby groups were unable to benefit to the same extent as the control groups. Knight (1992) suggests that the absence of practice effects in neuropsychological test results, when these have been reliably demonstrated in a non clinical population, may highlight possible cognitive deficits. Therefore, in both of these studies, the failure of the rugby group to benefit to the same extent as the control group on practice therefore highlights a group that is cognitively vulnerable at a post-season testing interval, which was not evident at the pre-season testing interval. Research by Fay et al. (2010) provides for a better understanding of these findings. Fay et al. (2010) highlight that cognitive reserve "is an important moderator of the outcome of mild traumatic brain injury in children and adolescents" (p. 94). It is believed the higher cognitive reserve an individual has, the more resilient they are to brain pathology (Stern, 2002). The rugby group's cognitive vulnerability is possibly a result of a lower cognitive reserve, which in turn is likely the result of the cumulative effects of the rugby group's long-term exposure to concussive and sub-concussive injury, resulting in a lower resilience to concussive injury. With regards to the present study, another key factor to consider in respect of cognitive reserve is that, as discussed previously, the rugby group is part of a relatively educationally vulnerable population. This was demonstrated in Part 1 of this study, where it was suggested that a possible link between cognitive reserve and quality of education exists, with a higher quality of education affording individuals the opportunity of acquiring a greater cognitive reserve, which in turn would represent a higher resilience to concussive injury.

In sum, the findings in Part 2 of this study provide additional support to the existing body of literature that suggests that athletes who compete in contact sport are at greater risk of chronic cognitive compromise as a result of exposure to concussive and sub-concussive injuries. These findings contradict the current definition of concussion, as suggested in the Zurich sport conference, that "concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury" (McCrory et al., 2009, p. 76).

4.4 Implications of Part 1 and Part 2 of this study

The findings of Part 1 and Part 2 of this study provide support for adopting an individualised approach, which incorporates neuropsychological testing, to managing concussive injury with athletes who compete in contact sport. An individualised approach would allow for the establishment of an individual pre-season baseline profile, which is achieved by means of using specific computerised concussion based neuropsychological tests, for example, ImPACT. Obtaining an accurate pre-season baseline profile is important, as any latter neuropsychological test performances are compared to this profile in order to investigate cognitive recovery following a concussive injury and inform decisions regarding return to play. If, for any reason, no accurate pre-season baseline profile is available, the use of appropriate demographically matched normative data provides for a reliable comparative against which a pre-season baseline profile could be compared in cases were an athlete is suspected of suffering from concussion. Ideally, a comprehensive approach to concussion management should make use of both an individualised pre-season baseline profile, as well as demographically matched normative data.

However, given the inherent difficulties in acquiring group specific normative data that adequately reflect the socio-economic and educational diversity of the South African context, the practice of establishing valid individual pre-season neurocognitive profiles for athletes becomes more urgent. These challenges were clearly demonstrated in the present study, where it was shown that Afrikaans ImPACT normative data obtained in respect of an Afrikaans cohort of rugby players who attended a Model C schooling system were generally depressed in comparison to existing normative data derived from English rugby players from relatively more advantaged schooling systems (both Private and Model C schools).

Further supporting the urgency of obtaining pre-season individual neurocognitive profiles for athletes is the fact that quality of education is also associated with cognitive reserve. Fay et al. (2010) suggested that socio-economic status, academic functioning and intelligence are seen to be good indicators of cognitive reserve, with higher academic functioning and intelligence being linked to higher cognitive reserve. Therefore, athletes who have a higher socio-economic status and are able to access more advantaged schooling systems, are in turn possibly more resilient to concussive injury as a result of a higher cognitive reserve, which is seen to be an important factor mediating the outcome following concussive injury.

Attesting to the importance of cognitive reserve as a mediating factor in concussion, the present study demonstrated that an Afrikaans rugby cohort from a relatively educationally vulnerable population (as shown in Part 1), presented at the pre-season testing interval with no demonstrable cognitive deficits. However, at the post-testing interval, the same group appears to be a cognitively vulnerable group, likely due to cumulative exposure to concussive and sub-concussive injuries as a result of their participation in contact sport, and also possibly due to the fact they are from a relatively educationally vulnerable population.

In the South African context, the majority of contact sport athletes are likely to be exposed to this combination of relatively poorer quality of education, as well as the cumulative effects of concussive and sub-concussive injury, both of which are associated with lower cognitive reserve capacity. This combination of factors places the majority of South African athletes at greater risk of cognitive compromise, and highlights the importance of: (i) adopting a modern approach to concussion management, with specific focus on obtaining individualised pre-season neurocognitive profiles, as well as, (ii) extending normative indicators for measures such as ImPACT, so that these accurately reflect the socio-cultural diversity that is a part of the South African context.

4.5 Evaluation of the present study

Generally it is considered that this was a well controlled study using a methodological approach that has been successfully adopted in a series of precursory studies (Shuttleworth-Edwards et al., 2008; Whitefield, 2006) As has been typical in the earlier studies, however (e.g. Shuttleworth-Edwards et al., 2008; Whitefield, 2006), a major limitation pertains to differences in the manner in which participants were selected for this study between the two comparative groups, due to perennial difficulties in gaining access to noncontact sports controls for such studies. In this instance, the rugby participants were selected on the basis of their membership to existing sporting teams, whereas the participants who made up the control group were selected on a voluntary informal basis. Therefore, it is possible that the control group may have been at risk of consisting of individuals of higher intellectual potential, as they might be the ones who would feel less threatened to undergo cognitive testing, and also because the control group was drawn from a much larger identified population than the rugby group.

However, to guard against such potential skewing of the comparative groups, it was ensured that these groups were closely matched in terms of age, years of education and estimated level of IQ, allowing for a close control of these variables. In addition, the variable of quality of education was controlled for by only selecting participants from an Afrikaans Model C schooling system. Further, the participants were all screened for potential confounding medical and psychiatric conditions. These very stringent inclusion and exclusion criteria allowed for the control of key extraneous variables that are known to affect the neuropsychological performance of individuals, which provides support for the validity of the findings of this study.

Another limitation in respect of this study is the small sample sizes, which is known to increase the risk of type II error. In order to guard against Type 1 error in the use of multiple comparisons, the Bonferroni adjustment towards greater stringency was adopted. However, this too may have increased the chance of Type II error. However, in spite of the small sample sizes and adjustment toward stringency in the statistical analyses, this study still found significant differences in respect of both Part 1 and Part 2, and these findings are commensurate with the findings of previous research investigating similar variables

A key strength of this study is that, at all the ImPACT testing intervals, identical testing and scoring procedures were followed. This is attributed to the fact that ImPACT test is computerised, and therefore, an exact testing and automated scoring procedure is followed each time that the test is administered and it is unlikely therefore that such basic methodological aspects may have served to confound the effects. Also, to be sure of tapping into the presence or absence of practice effects as distinct to differential test effects, the same version of the test (the baseline version) was used at both the pre-and post-season intervals, whereas this has been a weakness in other studies cited (Shuttleworth-Edwards et al., 2008).

4.6 Implication for future studies

Given the high prevalence of concussion in sport and the challenges of managing such injury, more research into the long-term effects of concussive and sub-concussive events is required, particularly in relation to educationally vulnerable groups. One of the problems at the moment is that, due to the professional nature of sport and the ability of relatively advantaged schools and communities to afford advice of professionals, most of the research is currently being done in these advantaged settings. However, given that cognitive reserve is associated with socio-economic variables, groups from poorer communities may be at greater risk of cognitive vulnerability as a result of exposure to concussive and sub-concussive injuries, and therefore further research with such groups is needed taking account of both socio-economic and cultural diversity (for example, at the South African township schools). In addition, children are at higher risk of cognitive and emotional/ behavioural compromise as a result of concussive injuries (Duff, 2009; Moser et al., 2007), and therefore, further research on younger populations would be valuable, given that children as young as nine are playing rugby at some South African schools.

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Appendix 1 - Headmaster consent form

RHODES UNIVERSITY
DEPARTMENT OF PSYCHOLOGY

Skoolhoof Toestemmingsvorm

Ek, _______________________________ die Skoolhoof van Hoërskool xxxxxxx, is ingelig oor die aard van die navorsing wat gedoen word deur Mnr Mark Horsman, onder die leiding van Prof. Ann Edwards, Rhodes University Psychology Department, oor die effek van harsingskudding in skole rugby. Hierdie navorsing is goedgekeur deur die Departement van Onderwys in die Oos-Kaap.

Ek verstaan dat:

1. Die navorser is 'n student wat navorsing doen as deel van die vereistes vir 'n Meesters graad in Kliniese Sielkunde aan die Rhodes Universiteit. Die navorser kan gekontak word op xxxxxxxx of by xxxxxxxx. Die navorsings projek is goedgekeur deur die Rhodes University Department of Psychology Research Projects and Ethics Review Committee en is onder die toesig van Professor Ann Edwards (xxxxxxxx of xxxxxxxx) aan die Rhodes Universiteit, Departement van Sielkunde.

2. Die navorsing sal twee groepe betrek (die rugby en nie-kontak groep). Altwee groepe sal geassesseer word deur middel van 'n gerekenariseerde neurosielkundige program (ImPACT). Die eerste assessering sal 'n demografiese vraelys, mediese geskiedenis en 'n neurosielkundige toetsbattery insluit wat ongeveer 30 minute neem om te voltooi. Toetsing sal plaasvind in die Hoërskool xxxxxxx rekenaar kamer op vooraf vasgestelde tye. Elke deelnemer in die navorsing sal middel/einde Februarie 2010 en weer aan die einde van die rugbyseisoen getoets word.

3. Addisioneel tot die ImPACT toets, sal 'n kontrole toets (die Ravens Progressive Standard Matrices) gedoen word om die ooreenkomste tussen die rugby en die nie-kontak groep te bepaal. Hierdie toets, wat 30 minute neem om te voltooi, sal onmiddelik na die eerste toetsgeleentheid gedoen word. Die doel van die bepaling is nie om intellektuele potensiaal te bepaal nie, maar eerder om 'n ooreenkoms tussen die twee groepe te bepaal.

4. As deel van die vereistes van die Departement van Onderwys sal hierdie navorsinngs projek op geen manier op die akademiese verpligtinge van die deelnemers nadeling beinvloed nie, en navorsiongs aktiwiteite sal slegs buite skooltye geskied.

5. Die data wat gedurende Feruarie/Maart 2010 en aan die einde van die rugby seisoen ingesamel word sal slegs in terme van groep uitslae gerbuik word geen individie se toets resultate sal bekend gemaak word nie.

6. Indien enige van die deelnemers 'n kopbesering sou opdoen tydens die 2010 rugby seisoen, sal addisionele ImPACT toetsing beskikbaar wees om te help met die bestuur van die herstelproses. Professor Ann Edwards sal alle sulke gevalle nasien en terugvoering verskaf aan die relevante persone, onder leiding van die ouers/voog. Hierdie data sal nie deel vorm van die navorsings projek nie. Hierdie toets kan egter nie gesien word as substituut vir en/of inmenging met mediese praktyke nie. Die navorsers sal nie veratwoordelikheid gehou word

vir mediese besluite gemaak deur mediese praktisyne of deelnemers op die basis van informasie wat versamel is gedurende die navorsing nie.

7. Deelname in die studie is vrywillig en ouers mag hul kind enige tyd onttrek van deelname in die studie of die deelnemer mag self enige tyd onttrek. Ouers of deelnemers word versoek om die rugby afrigter, Mnr xxxxxxx, skriftelik in kennis te stel ten opsigte van hul onttrekking van die navorsing.

8. Indien ‘n deelnemer nie wil deelneem of besluit om te onttrek, sal die besluit geen negatiewe rol speel in die deelnemer se deelname in en/ of span insluiting ten opsigte van enige sportaktiwiteite by Hoërskool xxxxxxx nie.

9. Die inligting versamel gedurende die 2010 rugby seisoen sal streng vertroulik hanteer word en sal slegs beskikbaar gestel word aan ouers en/of mediese personeel op versoek. Al die informasie versamel sal gebruik word vir navorsingsdoeleindes en mag anoniem gebruik word vir toekomstige navorsing en publikasie doeleindes onder die outeurskap van Rhodes University Psychology Department en die University of Pittsburgh Medical Center, Sport Concussion Program, USA.

10. Addisionele informasie ten opsigte van die navorsing is beskikbaar en kan aangevra word by Mnr Mark Horsman of Professor Ann Edwards, by die Rhodes University Psychology Clinic, (xxx) xxx-xxxx.

Hiermee gee ek die bogenoemde navorsers toestemming om genoemde navorsing te doen en gebruik te maak van die rekenaarkamer op vooraf vasgestelde tye.

Handtekening _______________________________ Datum:__________________

Appendix 2 - Rugby coach consent form

RHODES UNIVERSITY
DEPARTMENT OF PSYCHOLOGY

Rugby Afrigter Toestemmingsvorm

Ek, ________________________________ ,die rugby afrigter van Hoërskool xxxxxxx, is ingelig oor die aard van die navorsing wat gedoen word deur Mnr Mark Horsman, onder die leiding van Prof. Ann Edwards, Rhodes University Psychology Department, oor die effek van harsingskudding in skole rugby. Hierdie navorsing is goedgekeur deur die Departement van Onderwys in die Oos-Kaap.

Ek verstaan dat:

1. Die navorser is ‘n student wat navorsing doen as deel van die vereistes vir ‘n Meesters graad in Kliniese Sielkunde aan die Rhodes Universiteit. Die navorser kan gekontak word op xxxxxxxx of by xxxxxxxx. Die navorsings projek is goedgekeur deur die Rhodes University Department of Psychology Research Projects and Ethics Review Committee en is onder die toesig van Professor Ann Edwards (xxxxxxxx of xxxxxxxx) aan die Rhodes Universiteit, Departement van Sielkunde.

2. Die navorsing sal twee groepe betrek (die rugby en nie-kontak groep). Altwee groepe sal geassesseer word deur middel van ‘n gerekenariseerde neurosielkundige program (ImPACT). Die eerste assessering sal ‘n demografiese vraelys, mediese geskiedenis en ‘n neurosielkundige toetsbattery insluit wat ongeveer 30 minute neem om te voltooi. Toetsing sal plaasvind in die Hoërskool xxxxxxx rekenaar kamer op vooraf vasgestelde tye. Elke deelnemer in die navorsing sal middel/einde Februarie 2010 en weer aan die einde van die rugbyseisoen getoets word.

3. Addisioneel tot die ImPACT toets, sal ‘n kontrole toets (die Ravens Progressive Standard Matrices) gedoen word om die ooreenkomste tussen die rugby en die nie-kontak groep te bepaal. Hierdie toets, wat 30 minute neem om te voltooi, sal onmiddelik na die eerste toetsgeleentheid gedoen word. Die doel van die bepaling is nie om intellektuele potensiaal te bepaal nie, maar eerder om ‘n ooreenkoms tussen die twee groepe te bepaal.

4. As deel van die vereistes van die Departement van Onderwys sal hierdie navorsinngs projek op geen manier op die akademiese verpligtinge van die deelnemers nadeling beinvloed nie, en navorsiongs aktiwiteite sal slegs buite skooltye geskied.

5. Die data wat gedurende Feruarie/Maart 2010 en aan die einde van die rugby seisoen ingesamel word sal slegs in terme van groep uitslae gerbuik word geen individie se toets resultate sal bekend gemaak word nie.

6. Indien enige van die deelnemers ‘n kopbesering sou opdoen tydens die 2010 rugby seisoen, sal addisionele ImPACT toetsing beskikbaar wees om te help met die bestuur van die herstelproses. Professor Ann Edwards sal alle sulke gevalle nasien en terugvoering verskaf aan die relevante persone, onder leiding van die ouers/voog. Hierdie data sal nie deel vorm van die navorsings projek nie. Hierdie toets kan egter nie gesien word as substituut vir en/of inmenging met mediese praktyke nie. Die navorsers sal nie veratwoordelikheid gehou word

vir mediese besluite gemaak deur mediese praktisyne of deelnemers op die basis van informasie wat versamel is gedurende die navorsing nie.

7. Deelname in die studie is vrywillig en ouers mag hul kind enige tyd onttrek van deelname in die studie of die deelnemer mag self enige tyd onttrek. Ouers of deelnemers word versoek om my skriftelik in kennis te stel ten opsigte van hul onttrekking van die navorsing. Ek sal die inligting aan die bogenoemde navorsers voorsien.

8. Indien ‘n deelnemer nie wil deelneem of besluit om te onttrek, sal die besluit geen negatiewe rol speel in die deelnemer se deelname in en/of span insluiting ten opsigte van enige sportaktiwiteite by Hoërskool xxxxxxx nie.

9. Die inligting versamel gedurende die 2010 rugby seisoen sal streng vertroulik hanteer word en sal slegs beskikbaar gestel word aan ouers en/of mediese personeel op versoek. Al die informasie versamel sal gebruik word vir navorsingsdoeleindes en mag anoniem gebruik word vir toekomstige navorsing en publikasie doeleindes onder die outeurskap van Rhodes University Psychology Department en die University of Pittsburgh Medical Center, Sport Concussion Program, USA.

10. Addisionele informasie ten opsigte van die navorsing is beskikbaar en kan aangevra word by Mnr Mark Horsman of Professor Ann Edwards, by die Rhodes University Psychology Clinic, (xxx) xxx-xxxx.

Hiermee onderneem ek om saam te werk binne my kapasiteit waar moontlik met bogenoemde navorser gedurende die 2010 rugby seisoen.

Handtekening _________________________________ Datum:___________________

Appendix 3 - Parent consent form

RHODES UNIVERSITY
DEPARTMENT OF PSYCHOLOGY

Ouer/Voog Toestemmingsvorm

Geagte Ouer/ Voog,

Die Rhodes University Psychology Clinic is besig om navorsing te doen oor harsingskuddingsbestuur en evalueering in rugby. Die navorsing behels die toets van twee groepe deelnemers met die gebruik van die nuut vertaalde Afrikaanse weergawe van ‘n harsingskuddingbestuursprogram (ImPACT). Die twee groepe bestaan uit die Ope rugby Spanne en deelnemers wat nie aan kontak-sport deelneem nie. Hierdie navorsing is goedgekeur deur die Departement van Onderwys in die Oos-Kaap.

Spesifikasies:

1. Die navorser is ‘n student wat navorsing doen as deel van die vereistes vir ‘n Meesters graad in Kliniese Sielkunde aan die Rhodes Universiteit. Die navorser kan gekontak word op xxxxxxxx of by xxxxxxxx. Die navorsings projek is goedgekeur deur die Rhodes University Department of Psychology Research Projects and Ethics Review Committee en is onder die toesig van Professor Ann Edwards (xxxxxxxx of xxxxxxxx) aan die Rhodes Universiteit, Departement van Sielkunde.

2. Elke deelnemer sal ‘n ImPACT toets voltooi bestaande uit geheue en reaksie/terugvoertydstake wat redelik eenvoudig is en omtrent 30 minute sal neem. Na die afneem van die ImPACT toets tydens die eerste geleentheid, sal elke deelnemer ‘n pen-en-papier taak (die Ravens Progressive Standard Matrices) voltooi, wat ook omtrent 30 minute sal neem. Die toetsing sal plaasvind in Hoërskool xxxxxxx se rekenaarkamer op vooraf vasgestelde tye. Hierdie toetse sal in middel/einde Februarie 2010 (ImPACT en Ravens) en weer aan die einde van die rugby seisoen (slegs ImPACT) gedoen word.

3. As deel van die vereistes van die Departement van Onderwys sal hierdie navorsinngs projek op geen manier op die akademiese verpligtinge van die deelnemers nadeling beinvloed nie, en navorsings aktiwiteite sal slegs buite skooltye geskied.

4. Die data wat gedurende Februarie/Maart 2010 en aan die einde van die rugby seisoen ingesamel word sal slegs in terme van groepuitslae gerbuik word geen individie se toets resultate sal bekend gemaak word nie.

5. Indien enige van die deelnemers ‘n kopbesering sou opdoen tydens die 2010 rugby seisoen, sal addisionele ImPACT toetsing beskikbaar wees om te help met die bestuur van die herstelproses. Professor Ann Edwards sal alle sulke gevalle nasien en terugvoering verskaf aan die relevante persone, onder leiding van die ouers/voog. Hierdie data sal nie deel vorm van die navorsings projek nie. Hierdie toets kan egter nie gesien word as substituut vir en/of inmenging met mediese praktyke nie. Die navorsers sal nie veratwoordelikheid gehou word vir mediese besluite gemaak deur mediese praktisyne of deelnemers op die basis van informasie wat versamel is gedurende die navorsing nie.

6. Die navorsing sal nie skadelik wees vir die fisiese, geestelike of emosionele welstand van die deelnemer nie.

7. Al die informasie wat versamel word gedurende die 2010 rugby seisoen sal streng vertroulik hanteer word en slegs beskikbaar gestel word op versoek. Die bogenoemde informasie sal egter gebruik word vir navorsingsdoeleindes en mag anoniem (dus die individu se naam word nie bekend gemaak nie) gebruik word vir toekomstige navorsing en publikasie doeleindes deur Rhodes University Psychology Department en die University of Pittsburgh Medical Center, Sport Concussion Program, USA.

8. Deelname aan die studie is vrywillig en deelnemers mag op enige tydstip onttrek. ‘n Geskrewe brief moet na die rugby afrigter, Mnr xxxxxxx, gestuur word wat dan aan Mnr Mark Horsman deur gegee sal word.

9. Indien die deelnemer sou kies om nie verder deel te neem of te onttrek van die navorsingsprojek, sal dit op geen wyse sy deelname aan enige van die sportaktiwiteite van Hoërskool xxxxxxx benadeel nie.

10. Addisionele informasie oor die navorsing is beskikbaar en kan aangevra word by Mnr Mark Horsman of Professor Ann Edwards, by die Rhodes University Psychology Clinic, (xxx) xxx-xxxx.

Hiermee gee ek toestemming dat my seun mag deel neem aan die navorsingsprojek.

Naam van ouer/ voog:_____________________________________
Handtekening:__________________

Naam van my seun:_______________________________________Datum:_________________________

Appendix 4 - Participant consent form

RHODES UNIVERSITY
DEPARTMENT OF PSYCHOLOGY

Deelnemer Toestemmingsvorm

Ek, ________________________________ ‘n leerling van Hoërskool xxxxxxx, is ingelig oor die navorsingwatgedoen word deur die Rhodes University Psychology Clinic oor harsingskuddingsbestuur en evalueering.Hierdie navorsing is goedgekeur deur die Departement van Onderwys in die Oos-Kaap.

Ek verstaan dat:

1. Die navorser is ‘n student wat navorsing doen as deel van die vereistes vir ‘n Meesters graad in Kliniese Sielkunde aan die Rhodes Universiteit. Die navorser kan gekontak word op xxxxxxxx of by xxxxxxxx. Die navorsings projek is goedgekeur deur die Rhodes University Department of Psychology Research Projects and Ethics Review Committee en is onder die toesig van Professor Ann Edwards ((xxx) xxx-xxxx of xxxxxxxx) aan die Rhodes Universiteit, Departement van Sielkunde.

2. Ek die gerekenariseerde ImPACT harsingskuddingsbestuurstoets sal aflê wat bestaan uit geheue en reaksie/terugvoertydstake wat redelik eenvoudig is en omtrent 30 minute sal neem. Na die afneem van die ImPACT toets tydens die eerste geleentheid, sal ‘n pen-en-papier taak (die Ravens Progressive Standard Matrices) voltooi word wat ook omtrent 30 minute sal neem. Die toetsing sal plaasvind in Hoërskool xxxxxxx se rekenaarkamer op vooraf vasgestelde tye. Hierdie toetse sal in middel/einde Februarie 2010 (ImPACT en Ravens) en weer aan die einde van die rugby seisoen (slegs ImPACT) gedoen word.

3. As deel van die vereistes van die Departement van Onderwys sal hierdie navorsinngs projek op geen manier op die akademiese verpligtinge van die deelnemers nadeling beinvloed nie, en navorsiongs aktiwiteite sal slegs buite skooltye geskied.

4. Die data wat gedurende Februarie/Maart 2010 en aan die einde van die rugby seisoen ingesamel word sal slegs in terme van groep uitslae gerbuik word geen individie se toets resultate sal bekend gemaak word nie.

5. Indien ek ‘n kopbesering gedurende die 2010 rugby seisoen sou opdoen, sal addisionele ImPACT toetsing beskikbaar wees om te help met die bestuur van die herstelproses. Professor Ann Edwards sal alle sulke gevalle nasien en terugvoering verskaf aan die relevante persone, onder leiding van die ouers/voog. Hierdie data sal nie deel vorm van die navorsings projek nie. Hierdie toets kan egter nie gesien word as substituut vir en/of inmenging met mediese praktyke nie. Die navorsers sal nie veratwoordelikheid gehou word vir mediese besluite gemaak deur mediese praktisyne of deelnemers op die basis van informasie wat versamel is gedurende die navorsing nie.

6. Die navorsing nie skadelik sal wees vir my fisiese, geestelike of emosionele welstand nie.

7. Al die informasie wat versamel word gedurende die 2010 rugby seisoen sal streng vertroulik hanteer word en sal slegs beskikbaar gestel word met toestemming van die ouer/s . Die bogenoemde informasie sal egter gebruik word vir navorsingsdoeleindes en mag anoniem (dus die individu se naam word nie bekend gemaak nie) gebruik word vir toekomstige navorsing en publikasie doeleindes deur Rhodes University Psychology Department en die University of Pittsburgh Medical Center, Sport Concussion Program, USA.

8. Deelname aan die studie is vrywillig en ek kan op enige tydstip onttrek. ‘n Geskrewe brief moet na die rugby afrigter, Mnr xxxxxxx, gestuur word wat dan aan Mnr Mark Horsman deur gegee sal word.

9. Indien ek nie wil deelneem nie of besluit om te onttrek van die projek sal dit op geen wyse my deelname aan enige van die sportaktiwiteite van Hoërskool xxxxxxx benadeel nie.

10. Addisionele informasie oor die navorsing is beskikbaar en kan aangevra word by Mnr Mark Horsman of Professor Ann Edwards, by die Rhodes University Psychology Clinic, (xxx) xxx-xxxx.

Handtekening van deelnemer________________________________Datum:___________________

Appendix 5 - Department of Education approval letter (2009 and 2010)