THE NEUROPSYCHOLOGICAL AND ACADEMIC CONSEQUENCES OF REPEATED MILD AND VERY MILD TRAUMATIC BRAIN INJURIES IN RUGBY AT A SECONDARY SCHOOL

J.A. LAUBSCHER

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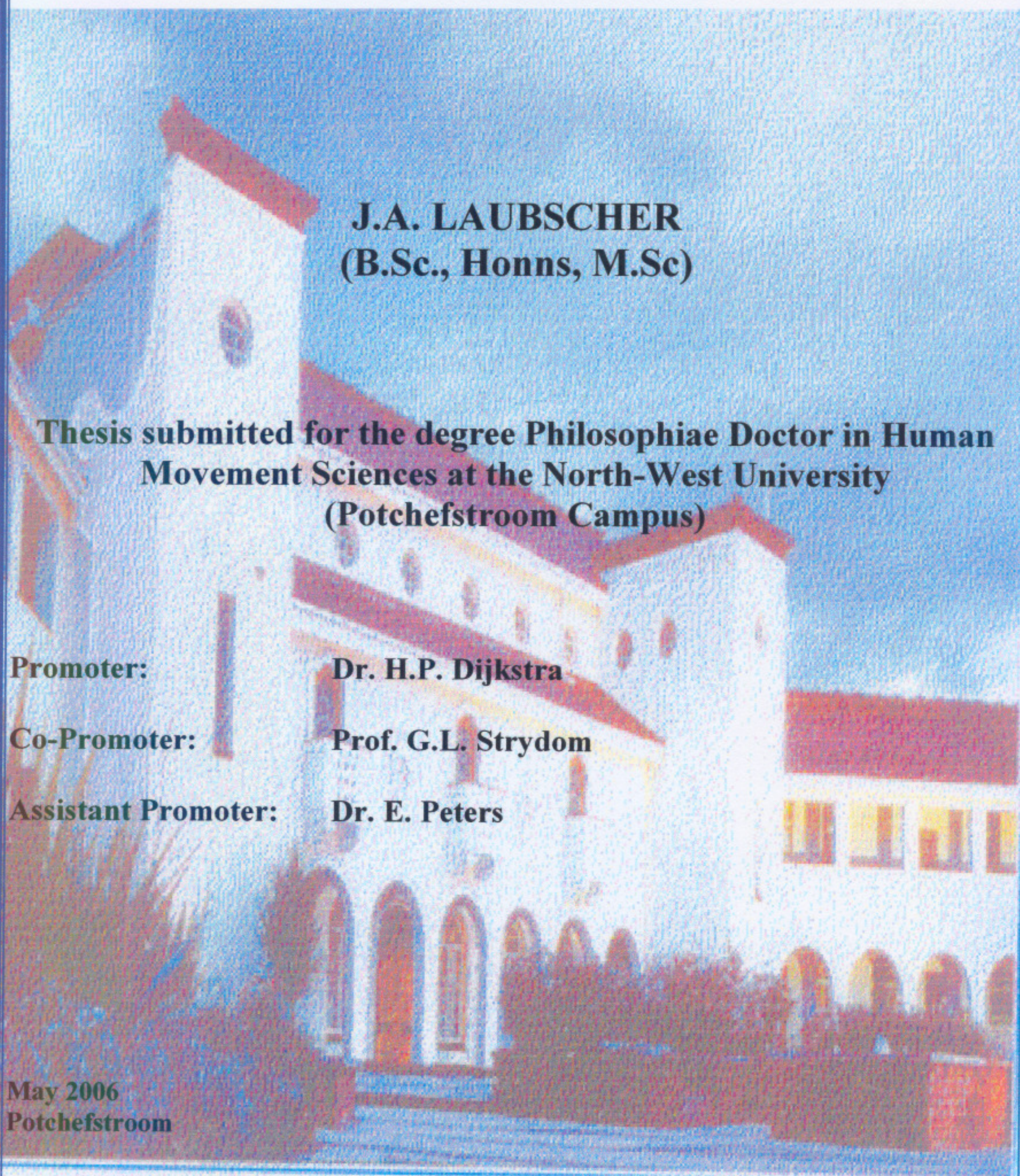

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May 2006
Potchefstroom

PREFACE

The successful completion of this thesis would not have being possible if the following persons didn't commit themselves to help me with this study. I would like to thank the following persons:

- Dr. H.P. Dijkstra from the School for Biokinetics, Recreation and Sport Sciences at the North-West University (Potchefstroom Campus) for his willingness to help me with this thesis as my Promoter. Thank you for all the help and exposure regarding this study and my work.
- Prof. G.L. Strydom from the School for Biokinetics, Recreation and Sport Sciences at the North-West University (Potchefstroom Campus) for his willingness to help me with this thesis as my Co-Promoter. Thank you for all the help and guidance.
- Dr. E. Peters, a Clinical Psychologist, for assisting me with this thesis as my Assistant Promoter. Thank you for your help and guidance, especially with the neuropsychological tests and information thereof.
- Prof. H.S. Steyn from the Statistical Consultation Service at the North-West University (Potchefstroom Campus) for his assistance with the statistical analysis of the data.
- Ms. C. Brink and Ms. M. Venter both were Psychology intern students at the time at the North-West University (Potchefstroom Campus) for the testing of the participants used in the study.
- Mr. Jopie Breed, Headmaster of Hoërskool Gimnasium, for allowing me to work with the learners of his school.
- Mr. Valie Bakkerus, the coach of Hoërskool Gimnasium first rugby team for his assistance in collecting data from each player.
- The learners (rugby players and control group) of Hoërskool Gimnasium who participated in the study.
- Mrs. Debbie Bakkerus for the initial language editing of the thesis.
- Ms. E. Uren for the final language editing.
- My parents for their love and support throughout the study.
- My wife Leanné for her love, support and inspiration throughout the study.
- **To my Heavenly Father for the ability that He gave me to use my intellect so that I could complete this thesis and my studies. All praise and honour to Him who gives us health and prosperity, for there is no end to His Love.**

J.A. Laubscher (Rines)
May 2006

DECLARATION

Hereby we the co-authors

- **Dr. H.P. Dijkstra**
- **Prof. G.L. Strydom**
- **Dr. E. Peters**

give permission that the research articles may form part of the candidate's PhD-thesis. The contribution of the co-authors was limited to their professional advice and guidance as study leaders towards the completion of the study.

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Promoter

Prof. G.L. Strydom
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ABSTRACT

The neuropsychological and academic consequences of repeated mild and very mild traumatic brain injuries in rugby at a secondary school.

Introduction - Physical activity can reduce the risk of contracting many of the 'diseases of the sedentary', such as coronary heart disease and cancer (Blair *et al.,* 1996). Recognition of this protective effect has led to the development of many programmes designed to promote the benefit of participation in sport and physical exercise (Hillary Commission, 1993; Nicholl *et al*., 1995). With participation in sport, especially contact sport, the risk for injuries increases, including injuries to the head and neck (Wilberger, 1993; Wekesa *et al*., 1996; Pettersen, 2002).

Mild traumatic brain injuries (MTBI) or concussion as used interchangeably in the literature (Maroon *et al.,* 2000; Wills & Leathem, 2001) are an important public health concern, due to the high incidence and frequently persisting symptomatology (Evans, 1992). Mild traumatic brain injury is defined as a complex patho-physiological process affecting the brain induced by traumatic biomechanical forces (Aubry *et al*., 2002; McCrory *et al*., 2004). A sub-concussive injury or very mild traumatic brain injury (vMTBI) may be defined as an apparent brain insult with insufficient force to cause hallmark symptoms of concussion (Jordan, 2000; Webbe & Bath, 2003).

The high incidence of sport related head injuries in South Africa is alarming, although the prevalence thereof is unknown and difficult to assess, as the seemingly trivial injuries frequently remain unreported (Roux *et al*., 1987). This is especially applicable in sport where a milder form of head injury is common. This is cause for concern as cumulative head injuries traditionally regarded as trivial or 'minor' may result in players running the risk of increasingly negative consequences following repetitive 'minor' head injuries. In contact sport such as rugby, players are at great risk of sustaining repetitive mild traumatic brain injuries. The negative outcome following these repetitive minor head injuries has been demonstrated by numerous studies on boxers and other athletes exposed to repeated MTBI and vMTBI (McLatchie *et al*., 1987). The incidence of vMTBI has not yet been researched in school rugby and this study is the first to report the incidence of vMTBI in a secondary school rugby team.

Objectives - The objectives of this study were to determine the incidence, the neuropsychological consequences and the effect on the academic performance of repeated mild (MTBI) and very mild traumatic brain injuries (vMTBI) in a secondary school rugby team during one playing season.

Methods - A cohort of 35 secondary school male rugby players divided into a vMTBI (group 1) (n=26) and a MTBI (group 2) (n=9) from a local secondary school's first and second team, was followed for a full competitive season by a trained Biokineticist, who was present at all the games and contact sessions played. All vMTBI and MTBI and the severity of these injuries were documented. A control (group 3) that consisted of 10 secondary school non-rugby players were compared with the vMTBI and MTBI groups.

The incidence of repeated MTBI and vMTBI in a secondary school rugby team were gathered by questionnaires and observation next to the field by a trained Biokineticist. Pre-season and post-season neuropsychological tests were conducted on the research groups and the control group. The neuropsychological tests that were conducted on the three groups were the Colour Trial Test 1 and 2 (CTT 1 + 2), the Symbol Digit Modalities Test (SDMT), the Wechsler Memory Scale-Revised (WMS-R) and the Standardised Assessment of Concussion (SAC). After each match played throughout the season the research group also completed a SAC test. The academic results of the final examination (year 1) of the year of the specific rugby season were obtained, as well as the academic results of the final examination of the preceding two years (year 2 and 3).

The programme STATISTICA (version 7.0, Stat soft, Tulsa, OK) was used to analyse the data. Descriptive statistics, one-way ANOVA's, two-way repeated measures ANOVA's, Post-hoc Tuckey HSD analysis and Pearson's product moment correlation were used for all the statistical analyses.

Results - This study of a secondary school rugby team has shown 726 vMTBI's and 18 MTBI's throughout one rugby season. This relates to 1951 vMTBI's per 1000 player hours and 48 MTBI's per 1000 player hours. Reductions in delayed memory *($p=0.01$)* from pre-season to post-season in a group of players with repetitive vMTBI's during a single rugby season were found. This was the first evidence of possible neurocognitive deficits towards delayed memory in very mild traumatic brain injuries at secondary school level. Statistically significant ($p \leq 0.05$) results of the SAC test totals between both the vMTBI and MTBI groups were documented in the different games throughout the rugby season and compared with the baseline test. No statistically significant differences ($p \leq 0.05$) between the pre-season and post-season's scores of the SAC test totals were documented. A decrease in academic performance in the subject Afrikaans (year 1 compared with year 2) with a p-value of $p=0.017$ (group 1) and $p=0.016$ (group 2) respectively was found.

Conclusion - The findings of this study indicate a high incidence of vMTBI in a cohort of secondary school rugby players in one season, a statistically significant reduction *($p=0.01$)* in delayed memory of the vMTBI rugby players and a statistically significant decrease in academic performance $p=0.017$ (group 1) and $p=0.016$ (group 2) in the subject Afrikaans from year 1 to year 2 final examinations.

Key words:

Closed head injuries, Concussion, Minor head injury, Mild Traumatic Brain Injury, Neuropsychological testing, Rugby

Sleutelterme:

Geslote kopbeserings, Konkussie, Geringe kopbeserings, Geringe Traumatiese brein beserings, Neuropsigologiese toetsing, Rugby

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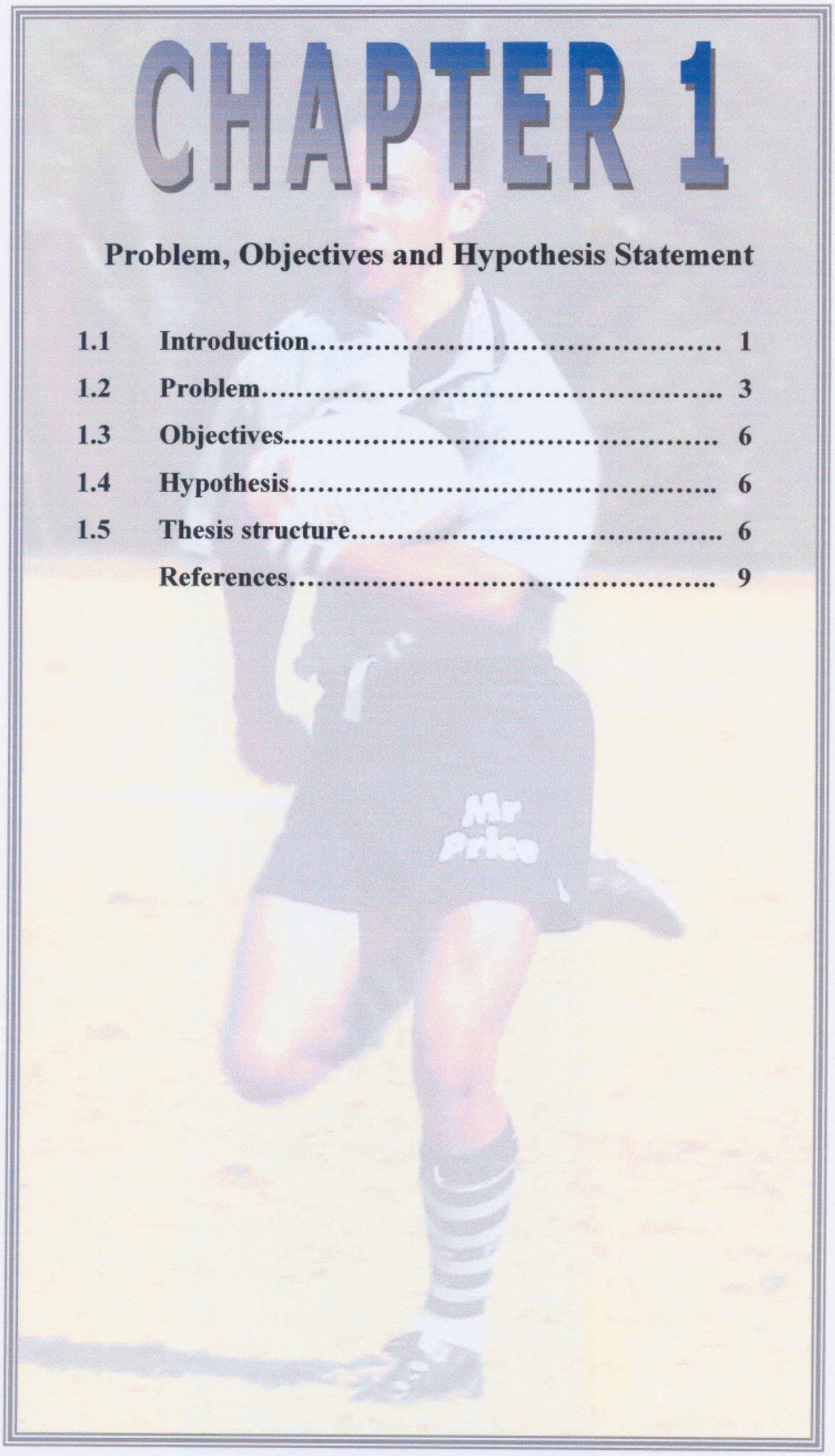
LIST OF ABBREVIATIONS

CISG	Concussion in Sport Group
CTT	Colour Trial Test
DSMT	Digit Symbol Modalities Test
IMPACT	Immediate Measurement of Performance and Cognitive Testing
LOC	Loss of Consciousness
MTBI	Mild Traumatic Brain Injury
MCGILL ACE	McGill Abbreviated Concussion Evaluation
N	Number of subjects in a study group
NHL	National Hockey League Physician Form
SAC	Standardised Assessment of Concussion
SCAT	Sideline Concussion Assessment Tool
SD	Standard Deviation
SIS	Second Impact Syndrome
TBI	Traumatic Brain Injury
vMTBI	Very Mild Traumatic Brain Injury
WMS-R	Wechsler Memory Scale - Revised



CHAPTER 1

Problem, Objectives and Hypothesis Statement

1.1 INTRODUCTION

Mild traumatic brain injuries (MTBI) or concussion, as used interchangeably in the literature (Maroon *et al.,* 2000; Wills & Leathem, 2001), are an important public health concern, due to the high incidence and frequently persisting symptomatology (Evans, 1992). The term concussion enables the use of an additional description within the spectrum of mild traumatic brain injuries, namely sub-concussive injuries that are explained in the literature as involving subtle changes in consciousness, difficult to detect with symptoms usually lasting seconds to minutes (De Villiers, 1987), therefore a very mild traumatic brain injury (vMTBI).

The high incidence of sport related head injuries in South Africa is alarming, although the prevalence thereof is unknown and difficult to assess, as the seemingly trivial injuries frequently remain unreported (Roux *et al.*, 1987). This is especially applicable in sports where a milder form of traumatic brain injury is common. This is cause for concern as cumulative traumatic brain injuries traditionally regarded as trivial or 'minor' may result in players running the risk of increasingly negative consequences following subsequent traumatic brain injuries. In contact sport such as rugby, players are at great risk of sustaining repetitive mild traumatic brain injuries (Roux *et al.*, 1987). The negative outcome following these repetitive minor traumatic brain injuries has been demonstrated by numerous studies on boxers and other athletes exposed to repeated MTBI and vMTBI (McLatchie *et al.*, 1987).

Mild traumatic brain injuries over the last decade could often have been overlooked because of shortcomings in the definition of concussion. The 1st International Conference on Concussion in Sport, Vienna (2001) and again at the 2nd International Conference on Concussion in Sport, Prague (2004), defined concussion and common features as follows:

Sports concussion is defined as a complex patho-physiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathological, and biomechanical injury constructs that may be utilised in defining the nature of a concussive head injury include (Aubry *et al.*, 2002; McCrory *et al.*, 2004):

- *Concussion may be caused either by a direct blow to the head, face, neck, or elsewhere on the body with an impulsive force transmitted to the head*
- *Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously*
- *Concussion may result in neuro-pathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury*
- *Concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course*
- *Concussion is typically associated with grossly normal structural neuro-imaging studies.*

Historically, concussions have been classified by different grading systems. The Vienna Statement abandoned this approach and the Prague group developed an understanding of concussion, which was categorised into either simple or complex concussion (McCrory *et al.*, 2004). These categories are described as follows:

- In simple concussion, an athlete suffers an injury that progressively resolves without complication over 7-10 days. In such cases, apart from limiting playing or training while symptomatic, no further intervention is required during the period of recovery and the athlete typically resumes sport without further problems (McCrory *et al.*, 2004)
- Complex concussion encompasses cases where athletes suffer persistent symptoms (including persistent symptom recurrence with exertion), specific sequelae eg. concussion convulsions, prolonged loss of consciousness (> 1 minute) or prolonged cognitive impairment following the injury. This group may also include athletes who suffer multiple concussions over time or where repeated concussions occur with progressively less impact force (McCrory *et al.*, 2004).

While the neuropsychological sequelae of mild head injury have been extensively documented (Gentilini *et al*, 1989), there appears to be a relative lack of prospective studies on the cumulative effects of repeated MTBI and vMTBI (Beilinsohn, 2001). This has particular relevance for athletes participating in contact sport, including rugby, as the physical nature of this sport predisposes the athletes to a greater risk of sustaining repeated mild traumatic brain injuries (McCrory *et al.*, 2001).

Previous studies in South Africa have demonstrated the negative effects of cumulative mild traumatic brain injuries (Reid, 1998; Ancer, 1999; Bold, 1999; Border 2000; Beilinsohn, 2001). In a study on the incidence of concussion, it was reported that concussion was the single most common injury in schoolboy rugby, making up 12% of all injuries and that several concussions often go unreported (Roux *et al.*, 1987).

More investigations into the neuropsychological effects of MTBI at school level should be undertaken (Beilinsohn, 2001). Previous studies have been restricted to incidence rates of concussion and did not focus on the neuropsychological consequences and outcomes.

In this study, the term MTBI refers to the term concussion and the term vMTBI refers to the term sub-concussive injuries and will be used interchangeably throughout this study.

1.2 PROBLEM

Injuries are inevitable in contact sport like rugby (Hammacher, 1991; Wekesa *et al.*, 1996; Kelly & Rosenberg, 1997). In fact rugby is considered to be one of the most dangerous sports being played (Wekesa *et al.*, 1996). Specific situations of the game such as the “set scrum”, the “ruck”, the “maul” or the “tackle” lead to heavy bodily contact (Finch *et al.*, 2001) and increase the risk of injury, especially to the head and neck (Clark *et al.*, 1990; Gibbs, 1993; Wekesa *et al.*, 1996; Pettersen, 2002). The vast majority, however, are minor head injuries (Gibbs, 1993; Wilberger, 1993) or so-called mild traumatic brain injury (MTBI).

Mild traumatic brain injuries and very mild traumatic brain injuries are subtle and often overlooked, thus referred to as a "silent epidemic". MTBI and vMTBI can be caused by the head being struck, the head striking an object or the brain undergoing an acceleration/deceleration movement (i.e. whiplash) [primary coup–contre-coup] without external trauma to the head (Cantu, 1992; Lezak, 1995; Cantu, 1995, Wilson, 1998; CASM Concussion Committee, 2000). MTBI can occur without the athlete ever suffering a loss of consciousness (Leininger, 1990; Evans, 1992; Wilberger, 1993). For this reason, it is sometimes difficult to recognise a vMTBI.

In a South African study it was found that approximately 50% of all secondary school rugby players had suffered an average of two concussions each during their rugby playing careers at school level (Roux *et al.*, 1987). Another study showed that 12% of all rugby related injuries in school rugby were concussions occurring mostly in the tackling and loose scrum situations (Roux *et al.*, 1987).

A matter of concern is the incidence and consequences of repetitive vMTBI in rugby. These injuries may on re-evaluation fulfil the criteria of MTBI. This means a rugby player has a blow or blows to the head in different situations of the game, plays on with no definite and immediate signs or symptoms of concussion, or the signs and symptoms may be short lived. The long-term outcome may represent possible neuropsychological effects or symptoms of concussion, which can include clinical symptoms, physical signs, cognitive impairment and loss of consciousness (Bruce *et al.*, 1982; Maddocks *et al.*, 1995; McCrory *et al.*, 2004). The clearest evidence of cumulative damage from repeated blows to the head is in the post-traumatic encephalopathy of boxing (Corsellis *et al.*, 1973; Bruce *et al.*, 1982; McLatchie *et al.*, 1987).

An adequate assessment of a player who sustains a head injury in rugby is important. The use of neuropsychological testing has been recognised as being a sensitive and effective method of determining subtle deficits associated with MTBI (Barth *et al.*, 1989; McCrory *et al.*, 1994; Brukner, 1996; Grindel *et al.*, 2001). Tests which are sensitive to the effect of subtle but diffuse brain damage may be extremely useful in determining baseline levels of functioning, post-injury levels of functioning and may also be used as an objective measure in determining whether a player is ready to return to play (McCrory *et al.*, 1994; Grindel *et al.*, 2001).

The application of neuropsychological testing in traumatic brain injuries has been shown to be of value and continues to contribute significant information in the evaluation thereof (Collins *et al.*, 1999; Grindel *et* al., 2001). It has been demonstrated that cognitive function should be an important component in any return to play protocol (Bleiberg *et al.*, 2004). It must be emphasized, however, that neuropsychological assessment should not be the sole basis of a return to play decision but rather be seen as an aid to the clinical decision-making.

The research questions that are posed in this study are the following, namely, to determine: (1) the incidence of mild traumatic brain injuries (concussion) and very mild traumatic brain injuries (sub-concussive injuries) in secondary school rugby players during a rugby season, (2) the neuropsychological consequences of these injuries and (3) the effect of these injuries on the academic performance of a secondary school rugby team compared with a sedentary control group.

Answers to these questions may help to understand the pathology of vMTBI and MTBI and shed more light on the incidence and consequences of this problem.

1.3 OBJECTIVES

The objectives of this study are to determine:

1.3.1 the incidence of repeated MTBI and vMTBI in a secondary school rugby team.

1.3.2 the neuropsychological consequences of repeated MTBI and vMTBI in rugby players in a secondary school rugby team.

1.3.3 the effect of repeated MTBI and vMTBI on the academic performance of the secondary school rugby players.

1.4 HYPOTHESIS

The following hypotheses are assumed:

1.4.1 the incidence of repeated MTBI and vMTBI is high amongst secondary school rugby players.

1.4.2 the repeated MTBI and vMTBI in rugby have significant neuropsychological consequences in a secondary school rugby team.

1.4.3 Repeated MTBI and vMTBI in rugby have a significantly negative effect on the secondary school rugby player's academic performance.

1.5 STRUCTURE OF THE THESIS

This thesis will be presented in article format as approved by the Senate of the North-West University and will be structured as follows:

Chapter 1: **Problem, objectives and hypothesis statement.** This chapter consist of the introduction, problem, objectives, and hypothesis statement. The references are listed at the end of the chapter according to the guidelines of the North West University.

Chapter 2: **Mild traumatic brain injuries (concussion) and very mild traumatic brain injuries (sub-concussive) in rugby – a literature review.** This chapter forms the literature survey of this study.

Chapter 3: **Article 1 – The incidence of very mild traumatic brain injuries and mild traumatic brain injuries in a secondary school rugby team during one season.** This chapter is presented in article format according to the guidelines of the African Journal for Physical, Health Education, Recreation and Dance with complete references. The information to authors for the African Journal for Physical, Health Education, Recreation and Dance is listed in Appendix B.

Chapter 4: **Article 2 – The neuropsychological status of a team of secondary school rugby players – comparison between very mild traumatic brain injury, mild traumatic brain injury and a sedentary control group.** This chapter is presented in article format according to the guidelines of the African Journal for Physical, Health Education, Recreation and Dance with complete references. The information to authors for the African Journal for Physical, Health Education, Recreation and Dance is listed in Appendix B.

Chapter 5: **Article 3 – The academic consequences of very mild traumatic brain injuries and mild traumatic brain injuries in a secondary school rugby team – A comparison between very mild traumatic brain injuries, mild traumatic brain injuries and a sedentary control group.** This chapter is presented in article format according to the guidelines of the South African Journal for Research in Sport, Physical Education and Recreation with complete references. The information to authors for the South African Journal for Research in Sport, Physical Education and Recreation is listed in Appendix B.

Chapter 6: **Summary, conclusions and recommendations and further research.** This chapter consists of a short summary of the study, a conclusion and further research recommended. The references are listed at the end of the chapter according to the guidelines of the North-West University.

Appendix A: The questionnaires, informed consent and neuropsychological tests used in the study are presented in this appendix.

Appendix B: The information to authors for the specific journals is presented in this appendix as well as other necessary information.

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CHAPTER 2

Mild traumatic brain injuries (concussion) and very mild traumatic brain injuries (sub-concussive) in rugby – a literature review

Content

MILD TRAUMATIC BRAIN INJURIES (CONCUSSION) AND VERY MILD TRAUMATIC BRAIN INJURIES (SUB-CONCUSSIVE) IN RUGBY – A LITERATURE REVIEW

2.1 INTRODUCTION:

Rugby is a famous contact sport in South Africa, and is becoming more and more competitive at all levels (Shuttleworth-Jordan *et al.*, 1993). To be competitive in rugby, one has to be conditioned for specific situations of the game that lead to heavy bodily contact such as the "set scrum", the "ruck", the "maul" and the "tackle" (Finch *et al.*, 2001). This means that the health ability, in particular the cognitive health of the athlete, is of importance to compete at their best (Collie *et al.*, 2001). Injuries are inevitable in contact sport like rugby (Wekesa *et al.*, 1996; Kelly & Rosenberg, 1997). The risk of sustaining traumatic brain injuries is increased whenever rugby players perform competitively, entailing physical contact with other players or objects (Wekesa *et al.*, 1996).

Mild traumatic brain injuries (MTBI) are an important public health concern, due to their high incidence and frequently persisting symptomatology (Maroon *et al.*, 2000). The term concussion enables the use of an additional description within the spectrum of mild traumatic brain injuries, namely sub-concussive injuries, which are explained in the literature as involving subtle changes in consciousness, difficult to detect with symptoms usually lasting seconds to minutes (De Villiers, 1987), thus a very mild traumatic brain injury (vMTBI). These injuries are frequently sustained in contact sport (including rugby), which is frequently used in research pertaining to mild traumatic brain injury (Roux *et al.*, 1987).

Note: In this study, the term mild traumatic brain injuries (MTBI) refers to the term concussion and the term very mild traumatic brain injuries (vMTBI) refers to the term sub-concussive injuries and will be used interchangeably throughout this article.

Most cases of mild traumatic brain injuries go unreported because the rugby player fears elimination from a team, being seen as a failure or letting down the team, the coach or the school (Cantu, 1986). The possible negative consequences are not always thought of. Despite this, there is still a high incidence of mild traumatic brain injuries reported in contact sport (Cantu, 1998). Furthermore, the incidence of very mild traumatic brain injuries may be underestimated because of the relatively subtle changes in consciousness and the difficulty to detect the injury (De Villiers, 1987).

The long-term effects of mild traumatic brain injuries have been inadequately researched, particularly in contact sport like rugby (Macciocchi *et al.,* 1998). This imply that mild traumatic brain injuries in contact sport including school rugby, needs to be taken seriously.

2.2 DESCRIPTION OF MILD AND VERY MILD TRAUMATIC BRAIN INJURY

2.2.1 Definitions of mild traumatic brain injury

The most common head injury in sport is concussion (Wilberger, 1993; Harmon, 1999). The word "concussion" has its origin in the Latin verb *conturere* meaning to shake violently (Kirkby, 2000; Maroon *et al.,* 2000).

In 1997 the Quality Standards Subcommittee of the American Academy of Neurology defined cerebral concussion as a traumatically induced alteration in mental status that may or may not involve a loss of consciousness (Kelly *et al.,* 1997).

Concussion can be defined as "a clinical syndrome characterised by immediate and transient post traumatic impairment of neurological function, such as alteration of consciousness, disturbance of vision and equilibrium due to brain stem involvement" (CASM Concussion Committee, 2000).

The definition of concussion that was accepted to include all limitations of previous definitions, was the definition presented at the 1st International Conference on Concussion in Sport, Vienna (2001) and again at the 2nd International Conference on Concussion in Sport, Prague (2004) by the Concussion in Sport Group (CISG):

Concussion is defined as a complex patho-physiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathological and biomechanical injury constructs that may be utilised in defining the nature of a concussive head injury include (Aubry *et al.*, 2002; McCrory *et al.*, 2004):

- *Concussion may be caused either by a direct blow to the head, face and neck or elsewhere on the body with an "impulsive" force transmitted to the head*
- *Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously*
- *Concussion may result in neuro-pathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury*
- *Concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course*
- *Concussion is typically associated with grossly normal structural neuro-imaging studies.*

Historically, concussions have been classified by different grading systems. The Vienna Statement abandoned this approach and the Prague Group developed a newly understanding of concussion which was categorised into either simple or complex concussion (McCrory *et al.*, 2004). These categories are described as follows:

- *Simple concussion is when an athlete suffers an injury, which progressively resolves without complication over 7-10 days. In such cases, apart from limiting playing or training while symptomatic, no further intervention is required during the period of recovery and the athlete typically resumes sport without further problems. Formal neuropsychological screening does not play a role in these circumstances, although mental status screening should be a part of the assessment of all concussed athletes. Simple concussion represents the most common form of this injury and can be appropriately managed by primary care physicians or by certified athletic trainers working under medical supervision (Gusckiewicz et al., 2004). The cornerstone of management is rest until all symptoms resolve and then a graded programme of exertion before return to sport. All concussions mandate evaluation by a medical doctor (McCrory et al., 2004).*

- *Complex concussion encompasses cases where athletes suffer persistent symptoms (including persistent symptom recurrence with exertion), specific sequelae eg. concussion convulsions, prolonged loss of consciousness (> 1 minute) or prolonged cognitive impairment following the injury. This group may also include athletes who suffer multiple concussions over time or where repeated concussions occur with progressively less impact force. In this group, there may be additional management considerations beyond simple return to play advice. Formal neuropsychological testing and other investigations should be considered in complex concussions. It is of great importance that physicians with specific expertise in the management of concussive injuries should manage such athletes in a multidisciplinary manner (McCrory et al., 2004).*

A team physician consensus statement in November 2005 defined concussion or mild traumatic brain injury as follows (Herring *et al.*, 2005):
Concussion or MTBI is a patho-physiological process affecting the brain induced by direct or indirect biomechanical forces.

Common features include:

- Rapid onset of usually short-lived neurological impairment, which typically resolves spontaneously
- Acute clinical symptoms that usually reflect a functional disturbance rather than structural injury
- A range of clinical symptoms that may or may not involve loss of consciousness (LOC)
- Neuro-imaging studies that are typically normal.

2.2.2 Definition of very mild traumatic brain injury

The term concussion enables the use of an additional description within the spectrum of mild traumatic brain injuries, namely sub-concussive injuries that are explained in the literature as involving subtle changes in consciousness, difficult to detect with symptoms usually lasting seconds to minutes (De Villiers, 1987), thus a very mild traumatic brain injury (vMTBI).

2.3. THE INCIDENCE OF vMTBI AND MTBI

Studies of the various forms of rugby show a high incidence of head and neck injuries, particularly among forward players. An Australian study found that concussion was one of the most frequent injuries in rugby league players (Seward *et al.,* 1993). According to the authors, the injury rate of head and neck injuries in rugby is the result of the high amount of bodily contact in the game and that forwards tend to be more involved in collisions than backs and therefore have higher injury rates.

Similarly, in South Africa, concussion is the most common injury in rugby making up 12% of all injuries (Roux *et al.*, 1987). The players in the highest teams tend to be at greater risk of obtaining a mild traumatic brain injury (Roux *et al.*, 1987).

A South African study reported that 10% of school rugby players sustained a concussion during a single rugby season, but this figure may underestimate the actual incidence since most MTBI and vMTBI with changes in consciousness rather than loss of consciousness, are unreported (Roux *et al.*, 1987). The same results were obtained in school American football where a 12% incidence of two concussions in the same season was reported (Wilberger, 1993).

A New Zealand study on a super 12-rugby team also showed that the most commonly injured body site was the head and face, accounting for 26.5% of the total injuries (Targett, 1998). Of these, 46.2% were lacerations requiring suturing or steri-strips, 38.5% were grade one head injuries as classified by Cantu (1986) and 14.3% were eye injuries (Targett, 1998).

A South African study on super 12 rugby teams showed a head injury incidence of 11 injuries per 1000 playing hours and most of these injuries were from the tackle situation (Holtzhausen *et al.*, 1999).

It is, therefore, evident that the stresses and impacts on the head and neck from tackling, scrumming and collisions between players can result in mild traumatic brain injuries (Shuttleworth-Jordan *et al.*, 1993) and that by the nature of the game, a rugby player is at greater risk for multiple head injuries or repetitive MTBI and vMTBI (Cantu, 1992).

One study showed a 20% occurrence of mild traumatic brain injuries amongst players in top school rugby teams and a growing concern towards the permanent and lasting effects following repeated mild traumatic brain injuries (Nathan *et al.,* 1983). The researchers also found that, on average, 10% of schoolboy rugby players will sustain a concussion during the course of the season. Recent research on professional rugby players has provided evidence for the presence of deleterious effects (e.g. learning difficulties, concentration problems, etc.) following repeated mild traumatic brain injuries and raises concerns about the short and long term cumulative effects of such injuries on the intellectual abilities of secondary school rugby players (Ackermann, 2000).

In a study that investigated the cumulative effects of MTBI and vMTBI on the cognitive functioning of secondary school rugby players, the neuropsychological test battery did not provide any substantial evidence of a higher level of neuropsychological impairment in the rugby players relative to the control group, or in the rugby forward players relative to the back line players (Beilinsohn, 2001). A greater frequency of post-concussive symptomology, such as easily angered, memory problems, clumsy speech and sleep difficulties was shown (Beilinsohn, 2001), however another study on high school rugby players showed initial stages of diffuse damage associated with mild traumatic brain injuries in the rugby forward group and provides some evidence for impairment of verbal learning and memory (Ackermann, 2000).

According to these two studies, there is still a lack of certainty about the definite outcome of the consequences on the cumulative effects of MTBI and vMTBI, therefore more research in this area is needed.

2.4 SUSTAINING A MILD TRAUMATIC BRAIN INJURY

To understand how a MTBI is sustained, one has to understand what forces produce skull and brain injuries:

- Maximum brain injury beneath the point of cranial impact (focal injury) is usually produced by a forceful blow to the resting movable head - primary coup injury (Cantu, 1995; Wilson, 1998)
- Maximum brain injury opposite the site of cranial impact (diffuse injury) is usually produced by a moving head impacting against an unyielding object - primary contre-coup injury (Cantu, 1995; Wilson, 1998)
- If a skull fracture is present, the first two dictums do not pertain, because the bone itself, whether it is transiently (linear skull fracture) or permanently (depressed skull fracture) displaced at the moment of impact, may directly injure brain tissue (Cantu, 1995).

Brain injuries have three types of stresses, namely compressive, tensile (the opposite of compressive, sometimes called negative pressure) and shearing (a force applied parallel to a surface) that can be generated by an applied force (Cantu, 1995; Sturmi *et al.,* 1998).

Tensile and shearing stresses are very poorly tolerated by neural tissue and are more likely to cause injury, while uniform compressive stresses are fairly well tolerated by neural tissue (Sturmi *et al.,* 1998; Kirkby, 2000). The cerebrospinal fluid (CSF) acts as a shock absorber, cushioning and protecting the brain by converting focally applied external stresses to a more uniform compressive stress (Kirkby, 2000). This is accomplished by the fluid following the contours of the sulci, something, which sets up damaging shearing forces (Cantu, 1995).

Despite the presence of CSF, shearing stresses may still be imparted to the brain. If rotational forces are applied to the head, shearing forces will occur at those sites where rotational gliding is hindered (Cantu, 1995). These areas are characterised by:

- Rough irregular surface contacts between the brain and skull, hindering smooth movement. This is most prominent in the frontal and temporal regions and explains why major brain contusions occur at these sites
- Dissipation of the CSF between the brain and skull. This explains the coup and contre-coup injuries. When the head accelerates prior to impact, the brain lags toward the trailing surface, thus squeezing away protective CSF and allowing for the shearing forces to be maximal at this site
- Dura mater-brain attachments impending brain motion. This brain lag actually thickens the layer of CSF under the point of impact, which explains the lack of coup injury in moving head injuries. On the other hand, when the head is stationary prior to impact, there is neither brain lag nor disproportionate distribution of CSF, accounting for the absence of contre-coup injury and the presence of coup injury.

2.5 ASSESSMENT AND MANAGEMENT OF MTBI

2.5.1 Evaluation and recovery

One of the most challenging problems faced by medical personnel responsible for the health care of athletes is the recognition and management of mild traumatic brain injuries. Full recovery from a MTBI before returning to contact sport is crucial. The current return to play guidelines remain controversial (Harmon, 1999; Johnston *et al.*, 2001). More than 90% of all MTBI that are sustained in sport are considered to be 'mild', characterised by no loss of consciousness, transient confusion and a brief duration of post-traumatic amnesia (Maddocks *et al.,* 1995; Cantu, 1997).

Mild traumatic brain injuries have been classified by different grading systems. The Vienna Statement abandoned this approach and the Prague Group developed a new understanding of concussion, which was categorised into either simple or complex concussion (McCrory *et al.*, 2004). Management and assessment of MTBI, including determination of when an athlete may return to play, are formulated in the following guidelines:

(1) Summary and Agreement Statement of the 2nd International Conference on Concussion in Sport, Prague (2004) by the Concussion in Sport Group (CISG): (McCrory *et al.*, 2004)
(2) Concussion (Mild Traumatic Brain Injury) and the Team Physician: A Consensus Statement (Herring *et al.*, 2005).

When a suspected diagnosis of MTBI is made on the sideline, it is applicable to both medical and non-medical personnel and can include clinical symptoms, physical signs, cognitive impairment and/or loss of consciousness. The athlete should be evaluated beginning with basic life support [danger, response (consciousness), airway, breathing and circulation] (McCrory, 1997; Harmon, 1999). The athlete must then be assessed as quickly as possible on the sideline if any one of the following symptoms or problems is present (McCrory *et al.*, 2004).

- Cognitive Features
  - Unaware of period, opposition, score of game
  - Confusion
  - Amnesia

- Typical symptoms (Maddocks *et al.*, 1995; Kelly *et al.*, 1997; Harmon, 1999):
  - Headache or pressure in the head
  - Balance problems or dizziness
  - Nausea
  - Feeling "dinged", "foggy", stunned or "dazed"
  - Visual problems (e.g. seeing stars or flashing lights, double vision)
  - Hearing problems (e.g. ringing in the ears)
  - Irritability or emotional changes
  - Other symptoms such as a subjective feeling of slowness and fatigue in the setting of an impact may indicate that a MTBI has occurred or has not fully resolved (Iverson *et al.*, 2004; McCrory *et al.*, 2004).

- Physical Signs (McCrory *et al.*, 2004):
  - Loss of consciousness/impaired conscious state
  - Poor coordination
  - Concussive convulsion/impact seizure
  - Gait unsteadiness/loss of balance
  - Slow to answer questions or follow directions
  - Easily distracted, poor concentration
  - Displaying inappropriate emotions (e.g. laughing, crying)
  - Vomiting
  - Vacant stare/glassy eyed
  - Slurred speech
  - Personality changes
  - Inappropriate playing behaviour (e.g. running the wrong direction)
  - Significantly decreased playing ability.

Of these symptoms, confusion and amnesia are emphasized as the hallmarks of MTBI and may occur immediately after a blow to the head or several minutes later (Kelly *et al.*, 1997; Kirkby, 2000).

Sideline evaluation of cognitive function is an essential component in the assessment of this injury. Brief neuropsychological test batteries that assess attention and memory function have been shown to be practical and effective. Such tests includes the Maddocks questions (Maddocks *et al.,* 1995) and the Standardised Assessment of Concussion (SAC) (McCrea *et al.,* 1998), which is included in the Sideline Concussion Assessment Tool [SCAT] (McCrory *et al.*, 2004). It should also be recognised that the appearance of symptoms may be delayed several hours following a concussive episode.

The player should then be removed from the field of play for a more detailed neurological assessment. Using all the information, possible decisions may be made on the severity of the MTBI, a simple or complex concussion and when to return to play. It should be noted that return to play in a contact activity while still symptomatic is very dangerous (CASM Concussion Committee, 2000).

Neuropsychological testing is one of the cornerstones of MTBI evaluation and contributes significantly to both the understanding of the injury and the management of the individual (Grindel *et* al., 2001). It has been demonstrated that cognitive function should be an important component in any return to play protocol (Bleiberg *et al.*, 2004). To maximise the clinical utility of such neuropsychological assessment, baseline testing is recommended (Aubry *et al.*, 2002). It must be emphasized, however, that neuropsychological assessment should not be the sole basis of a return to play decision, but rather be seen as an aid to the clinical decision-making.

Only in the past few decades has there been interest in studying the neuropsychological consequences of concussion. A range of neuropsychological deficits has been reported after mild traumatic brain injuries. The deficits include disturbances of new learning and memory, planning, the ability to switch mental 'set' and reduced attention and speed of information processing (Lezak, 1995). Neuropsychological testing enables more accurate assessment of MTBI and better decision making for return to play (McCrory, 1997; Maroon *et al.*, 2000).

It has been shown that cognitive recovery may precede or follow resolution of clinical symptoms (Aubry *et al.*, 2002). In the consideration of injury recovery or return to play, such test strategies must access the cognitive domains of information processing, planning, memory and switching mental set. Numerous paradigms are in current use. Examples of these include paper and pencil tests (McGill ACE, SAC, SCAT), condensed batteries (McGill ACE), comprehensive protocols administered by neuro-psychologists (NHL, Australian football) and computerised test platforms – for example, IMPACT, CogSport, ANAM, Headminders (Aubry *et al.*, 2002).

Overriding principles common to all neuropsychological test batteries are the need for and benefit of baseline pre-injury testing and serial follow up. Recent work with computerised platforms suggests that performance variability may be a key measure for diagnosis of acute MTBI, even in the absence of a baseline test (Aubry *et al.*, 2002).

Inherent problems with most neuropsychological tests include the normal ranges, sensitivity and specificity of tests, practice or learning effect as well as the observation that players may return to baseline while still symptomatic (Grindel *et al.*, 2001). In part, these may be a problem of the currently available pen and paper tests. Computerised testing using infinitely variable test paradigms may overcome these concerns.

Computerised testing also has the logistical advantage that the team doctor may administer the test or is web based rather than having to employ a neuro psychologist for a formal assessment (Aubry *et al.*, 2002). Another advantage that computerised tests have over pen and paper tests is that it allows detecting subtle impairments such as those expected in mildly concussed athletes (Collie *et al.*, 2001). These include randomised stimulus presentation, typically high-retest reliability, lack of floor and ceiling effects and the ability to assess a range of cognitive domains in a short period of time (Collie *et al.*, 2001).

Individual players vary with respect to their levels of performance on tests of mental processing speed, attention/concentration, memory and motor speed (Maroon *et al.,* 2000). Therefore, pre-season baseline testing of athletes is essential. Without the knowledge of a baseline score of each athlete before a vMTBI or MTBI, it is difficult to assess whether any deficits detected during testing are attributable to the effects of the vMTBI or MTBI, or to other unrelated factors. When an athlete sustains a vMTBI or MTBI, return to play can be determined by guidelines and neuropsychological tests (Aubry *et al.*, 2002).

This means an athlete could return more safely and quickly to play than before, if he is totally symptom free, making assessment more efficient with the assistance of neuropsychological testing (McCrory, 1997).

2.5.2 Stepwise return to play after a vMTBI or MTBI

The majority of injuries will be simple concussions and such injuries recover spontaneously over several days. In these situations, it is expected that an athlete will proceed rapidly through the stepwise return to play approach (CASM Concussion Committee, 2000; McCrory *et al.*, 2004). During this period of recovery in the first few days following an injury, it is important to emphasise to the athlete that physical and cognitive rest is required. Activities that require concentration and attention may exacerbate the symptoms and as a result delay recovery.

The return to play following a vMTBI or MTBI is a stepwise approach (McCrory *et al.*, 2004):

Step 1: No activity, complete rest. Once medically cleared asymptomatic, proceed to step 2. Continue to proceed to the next step if asymptomatic. If symptoms occur, drop back to a step where there are no symptoms, and try to progress again

Step 2: Light aerobic exercise such as walking or stationary cycling, no resistance training

Step 3: Sport specific activity (e.g., running grids in rugby). Progressive addition of resistance training at step 3 or 4

Step 4: Non-contact training drills
Step 5: Full contact training after medical clearance
Step 6: Game play.

2.5.3 Premature return to play:

Premature return to play may place the athlete at further risk of a repeat injury, possibly resulting in cumulative damage or even a catastrophic outcome, for example Second-impact syndrome, Post-concussion syndrome and the Punch-drunk syndrome (Harmon, 1999; McCrory, 2001; Hinton-Bayre, 2002).

Second-impact syndrome (SIS) is defined as occurring when an athlete who has sustained an initial head injury, most often a concussion, sustains a second head injury before symptoms associated with the first have fully cleared (Cantu & Voy, 1995; Cantu, 1996; McCrory *et al.*, 2001). SIS can occur during any sport that can produce a blow against the head (Cantu & Voy, 1995).

A second blow to the head, even a minor one, results in a loss of cerebrovascular auto regulation, leading to malignant brain swelling and a marked increase in intracranial pressure, which could be fatal (Wilberger, 1993; Cantu & Voy, 1995; Kelly & Rosenburg, 1997; McCrory & Berkovic, 1998; McCrory, 2001). Boxers are most likely to suffer from second-impact syndrome, because of repetitive head impacts, but this is not frequently seen (McCrory & Berkovic, 1998).

Repeated concussions may result in cumulative neurologic damage, even when months or years separate the injuries (Kelly *et al.*, 1991; Kelly & Rosenburg, 1997; Kirkby, 2000). The most striking example of this is the so-called "punch drunk" syndrome that sometimes occurs in boxers (Jordan, 1996; Harmon, 1999; Kirkby, 2000). For this reason, a thorough history of previous concussions should be obtained (Roberts, 1992).

Returning to play prematurely may increase the likelihood of the development of post-concussion syndrome (PCS) (Hinton-Bayre, 2002). This syndrome is described as the emergence and variable persistence of symptoms following an episode of concussion and is characterised by fatigue, headaches, equilibrium disturbances or difficulty in concentrating, sleep disturbances, anxiety, depression, loss of appetite, co-ordination and hallucinations that may persist for weeks to months after the initial injury (Harmon, 1999; Johnston *et al.*, 2001).

2.6 PREVENTION OF HEAD INJURIES

There are relatively few methods by which MTBI may be minimised in sport, especially in rugby. The brain is not an organ that can be conditioned to withstand injury like the musculoskeletal system. Protective equipment may be one of the methods to minimise the number and seriousness of injuries (Wekesa *et al.*, 1996). Rule changes and rule enforcement may also play a role in reducing and preventing concussions (Aubry *et al.*, 2002).

2.6.1 Headgear

Most studies of rugby injuries report that head and facial injuries account for 14-27% of all injuries (Gerrard *et al.*, 1994; Bird *et al.*, 1998). Of these, 60-80% are lacerations to the face or scalp and 5-10% are concussion.

In sport like baseball where high-speed collisions are possible, or falls onto hard surfaces such as in ice hockey, there is published evidence for a helmet to reduce the rate of head injuries (Honey, 1998; Benson *et al.,* 1999). On the other hand, in sports like rugby union, rugby league and Australian football, no sport specific headgear has shown to be effective in reducing head injuries (Gibbs, 1994; Wilson, 1998; McIntosh & McCrory, 2001).

The protective headgear used in rugby (referred to as a 'scrum cap') has been proposed as a means of protecting the head from lacerations and theoretically reducing the risk of mild traumatic brain injuries (Wilson, 1998). The role of protective headgear is to attenuate the forces of impact, to reduce the accelerations at the point of impact, to distribute the force over a larger area and to protect the soft tissue and bone from surface abrasions caused by frictional forces (Wilson, 1998).

2.6.2 Mouth guards

The mouth guard is a resilient device or appliance, which is placed inside the mouth to protect against injuries to the teeth, lacerations to the mouth and fractures and dislocations of the jaw (Gibbs, 1994; Chalmers, 1998). The evidence that mouth guards reduce mild traumatic brain injuries are limited and not prospectively tested (McCrory, 1999).

2.6.3 Rule changes and enforcement

Where a clear-cut mechanism for a certain injury is implicated in a particular sport, the consideration of a rule change needs to be taken. Examples are the rule changes that were made to ban spear tackles, tackling above shoulder height and tackling with a straight stiff arm, therefore reducing the incidence of possible catastrophic head and neck injuries (Gibbs, 1994; Finch *et al.,* 2001).

A critical aspect that needs to be taken seriously is the emphasis on rule enforcement (Johnston *et al.,* 2001). Sport in general would be much safer if the rules were strictly and correctly enforced. Referees and linesmen should have sufficient training to enforce and interpret the rules correctly and consistently. This may further reduce the rate of injuries, especially head and neck injuries (Herring *et al.,* 2005).

2.6.4 Physical conditioning

Physical conditioning is important not only to prevent injuries but also to perform at one's best in a specific sport (Cantu, 1992; Rotem & Davidson, 2001). Coaches should emphasise that general fitness is the basis for all sport participation and that pre-seasonal training should be encouraged (strengthening, stretching and cardiovascular exercises) (Rotem & Davidson, 2001). Fitness exercises (speed, agility, power and endurance) should be included in training sessions as well as the enhancement of specific skills required for a certain sport (Rotem & Davidson, 2001).

In the early stages of the development of a sportsman, every emphasis should be given to broad-based participation opportunities to enhance general motor development. All training sessions should include warm-up and cool-down periods and flexibility exercises (Micheli *et al.,* 2000). Physical conditioning, especially to the neck and shoulder muscles, could be of value to reduce impact forces transmitted to the brain and can be enhanced by resistance training.

2.6.5 Education

Another important aspect of prevention is the education of team health professionals (Physicians, Physiotherapists, Biokineticist) and coaches towards the recognition of very mild and mild traumatic brain injuries, the seriousness of such an injury and the consequences if inappropriate care is taken (Johnston *et al.*, 2001).

Health professionals must take steps to improve their knowledge and understanding of the organised sport environment as well as the risk factors and safety factors inherent to this type of sport participation (Cantu, 1992). Physicians should monitor the health and safety of children involved in organised sport whenever possible, in particular those involved in collision sport (Cantu, 1992). Coaches, the participants and healthcare providers should participate in special programmes of education regarding the detection of MTBI and vMTBI, its clinical features, assessment techniques and principles of safe return to play (Cantu, 1992; Aubry *et al.*, 2002).

They should have credentials that encompass the techniques and skills of youth sport, the specific safety risks of children's sport, the psychology and sociology of children and adolescents and the physiology of growth and development as it relates to physical activity during childhood and adolescence as well as common medical related issues (Micheli *et al.*, 2000).

2.7 CONCLUSIONS

The most common sport related head injury is mild traumatic brain injury, which may vary widely in severity (Wilberger, 1993; Harmon, 1999). Very mild traumatic brain injuries are probably more frequent but more difficult to recognise because of their subtle nature.

Mild traumatic brain injuries (MTBI) or concussion as used interchangeably in the literature (Maroon *et al.*, 2000) are an important public health concern due to their high incidence and frequently persisting symptomatology (Evans, 1992). The term concussion enables the use of an additional description within the spectrum of mild traumatic brain injuries, namely sub-concussive injuries that are explained in the literature as involving subtle changes in consciousness, difficult to detect with symptoms usually lasting seconds to minutes (De Villiers, 1987), therefore a very mild traumatic brain injury (vMTBI). These injuries are frequently sustained in contact sport (including rugby), which is frequently used in research pertaining to mild traumatic brain injury.

More research on vMTBI is needed to understand the nature, incidence, consequences and long-term effects on the rugby player.

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CHAPTER 3

The incidence of very mild traumatic brain injuries and mild traumatic brain injuries in a secondary school rugby team during one season

Content

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THE INCIDENCE OF VERY MILD TRAUMATIC BRAIN INJURIES AND MILD TRAUMATIC BRAIN INJURIES IN A SECONDARY SCHOOL RUGBY TEAM DURING ONE SEASON

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Abstract

The incidence of mild (concussive) and very mild (sub-concussive) traumatic brain injuries in secondary school rugby players was documented in this study. The study group consisted of thirty-five (35) rugby players (group 1 = vMTBI & group 2 = MTBI) and ten (10) non-rugby players were used as a control (group 3). The control group consisted of schoolboys that did not play any contact sport. In a single rugby season, 726 very mild traumatic brain injuries (1951 vMTBI per 1000 player hours) and 18 mild traumatic brain injuries (48 MTBI per 1000 player hours) were sustained in 372 player hours of match play. Most of these injuries took place in the tackle (vMTBI [32%] and MTBI [61%]) and loose scrum (vMTBI [40%] and MTBI [39%]) situation. The forwards sustained more vMTBI and MTBI than the backs. The incidence of vMTBI has not yet been researched in school rugby and this study is the first to report the incidence of vMTBI in a secondary school rugby team. The findings of this study indicate a high incidence of vMTBI in a cohort of secondary school rugby players in one season.

Keywords: Concussion; Headgear; Mouth guards; Rugby; Sub-concussive injuries; Traumatic brain injuries.

Note: In this study, the term mild traumatic brain injuries (MTBI) refers to the term concussion and the term very mild traumatic brain injuries (vMTBI) refers to the term sub-concussive injuries and will be used interchangeably throughout this article. Group 1 = vMTBI, Group 2 = MTBI & Group 3 = Control Group.

3.1 INTRODUCTION

Rugby is an international contact sport involving two teams of 15 players in which the ball is carried, thrown, passed by hand and kicked (Williams, 1994). Impact, collision at speed and body contact is an inherent part of the sport and can result in significant musculoskeletal trauma (Gibbs, 1993). Body contact occurs during many phases of play including tackling, scrumming, line-outs, rucks and mauls (Finch, McIntosh & McCrory, 2001). Muscle contusions, ligament sprains and similar soft tissue damage are the less severe yet more commonly seen injuries in rugby. Closed head injuries and mild traumatic brain injuries (MTBI), joint dislocation and fractures on the other hand, represent the more serious end of the spectrum (Bird, Waller, Marshall, Alsop, Chalmers & Gerrard, 1998).

Mild traumatic brain injuries (MTBI) are an important public health concern, due to their high incidence and frequently persisting symptomatology (Maroon, Lovell, Norwig, Podell, Powell & Hartl, 2000; Wills & Leathem, 2001). The term concussion enables the use of an additional description within the spectrum of mild traumatic brain injuries, namely sub-concussive injuries that are explained in the literature as involving subtle changes in consciousness, difficult to detect with symptoms usually lasting seconds to minutes (De Villiers, 1987), therefore a very mild traumatic brain injury (vMTBI).

A very mild traumatic brain injury may be defined as an apparent brain insult with insufficient force to cause hallmark symptoms of concussion (Jordan, 2000; Webbe & Bath, 2003).

The most common head injury in rugby is MTBI and school rugby players are the most eligible to sustain a MTBI. Roux, Goedecke, Visser, Van Zyl & Noakes (1987) indicated that 12% of all injuries in schoolboys and 10% in adults are concussions. Other studies found that about 50% of all secondary school rugby players have suffered an average of two concussions each during their rugby playing careers at school (Roux *et al.*, 1987).

Once a MTBI has occurred, the player becomes as much as four to six times more likely to sustain a second MTBI (Cantu, 1996; Harmon, 1999; Cantu, 2003). For this reason a balance must be reached between maintaining a competitive edge in a sport and ensuring participant safety (Cantu, 1996; Harmon, 1999; Cantu, 2003). Frequently, the loss of objectivity on the part of the rugby player, coaches and spectators is an unfortunate and potentially harmful bias (Cantu, 1996; Harmon, 1999; Cantu, 2003).

It is noticed more than before that school rugby involves many of injuries, in particular very mild traumatic brain injuries [vMTBI]) that go unreported due to the lack of knowledge to recognise a possible MTBI, the lack of good medical treatment at the sideline and the ignorance by coaches and rugby players to follow a well managed plan towards return to play (Cantu, 1996; Harmon, 1999; Cantu, 2003). The potential for repeated vMTBI to cause equivalent, if not greater damage than a single mild traumatic brain injury was proposed decades previously by Tysvaer & Lochen (1991).

Although many have researched MTBI in sport (McIntosh & McCrory, 2001; Cantu, 2003), vMTBI in rugby has not been researched. The rationale for wrapping vMTBI into the context of MTBI is that such traumatic injuries exist on a continuum of histologically based damage (Webbe & Bath, 2003). For the very reason that vMTBI is not so easily marked as MTBI, however, it is conceptually problematic to make the link to any observed impairment.

The major impetus for considering vMTBI outcomes is the fact that such injuries are common in sport such as soccer, football and boxing (Jordan, 2000) and could be expected in rugby. Indeed, boxing has served as the primary laboratory for assessing the role of multiple MTBI and vMTBI in producing neurocognitive impairment (Jordan, 2000). The main difficulty in interpretation is determining where the effects of vMTBI end and those of MTBI begin.

The aim of this study is to document the incidence of vMTBI and MTBI in a secondary school rugby team in a single rugby season.

3.2 MATERIALS AND METHODS

3.2.1 Selection of research groups

The research group in this study was rugby players playing for the first and second teams at a local secondary school. Thirty-five (35) rugby players participated divided into two groups (group 1 = vMTBI & group 2 = MTBI) [players from the school's first (n=15) and second (n=15) teams and reserve players (n=5) playing for the third team] and ten (10) non-rugby players were used as a control (group 3). The control group consisted of schoolboys that did not play any contact sport and was selected randomly from the same school as the rugby players, with the same age, gender and education level. The random test sample was selected as follows the controls were selected from the grade 11 (aged 17) and grade 12 (aged 18) groups of the school by eliminating all the rugby playing learners and using the chance figures according to Steyn, Smit, Du Toit & Strasheim (1995) to select the control group randomly. Learners with diagnosed learning disabilities, previous concussions, epilepsy and drug abuse were not considered for the control group of this study. After the study was discussed with the participants and in letter format with the parents, all the participants, parents or guardians gave informed consent. The Ethics Committee of the North-West University approved the study.

3.2.2 Measuring instruments - Questionnaires

The questionnaire's information was based on the following definitions of MTBI and vMTBI as criteria.

The definition of concussion that was accepted to include all limitations of previous definitions, was the definition presented at the 1st International Conference on Concussion in Sport, Vienna (2001) and again at the 2nd International Conference on Concussion in Sport, Prague (2004) by the Concussion in Sport Group (CISG).

Concussion is defined as a complex patho-physiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathological and biomechanical injury constructs that may be utilised in defining the nature of a concussive head injury include (Aubry, Cantu, Dvorak, Graf-Baumann, Johnston, Kelly, Lovell, McCrory, Meeuwisse & Schamasch, 2002; McCrory, Johnston, Aubry, Cantu, Dvorak, Graf-Baumann, Kelly, Lovell & Schamasch, 2004):

- *Concussion may be caused either by a direct blow to the head, face, and neck or elsewhere on the body with an "impulsive" force transmitted to the head*
- *Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously*
- *Concussion may result in neuro-pathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury*
- *Concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course*
- *Concussion is typically associated with grossly normal structural neuro-imaging studies.*

The term concussion enables the use of an additional description within the spectrum of mild traumatic brain injuries, namely sub-concussive injuries which are explained in the literature as involving subtle changes in consciousness difficult to detect with symptoms usually lasting seconds to minutes (De Villiers, 1987), therefore a very mild traumatic brain injury (vMTBI).

- Demographic information – questionnaire (Appendix A)

  This questionnaire was used to collect the demographic information of the rugby players in the pre-season.

- After match evaluation – questionnaire (Appendix A)

  This questionnaire was used to determine the incidence of mild and very mild traumatic brain injuries after a game of rugby. This questionnaire consisted of a section that the researcher had to complete after each match and practice session played. This section was based on sideline observation by the researcher while the match and practice session was played. The researcher observed and noted all the vMTBI and MTBI when play was officially stopped for the injury. The researcher also observed and noted some vMTBI during the time of play.

3.2.3 Statistical analysis

The programme STATISTICA (version 7.0, Stat soft, Tulsa, OK) was used to analyse the data and divide it into the following statistical analysis. Descriptive statistics were used on each group to obtain the means and standard deviation of their ages as shown in Table 3.1. Descriptive statistics were also used on each group to obtain the means and standard deviation of the incidence of repeated mild and very mild traumatic brain injuries in the specific playing phases, playing positions and in the protective equipment used as shown in Table 3.2 to 3.3 and in Figure 3.1 to 3.3.

3.3 RESULTS AND DISCUSSION

There has been no prospective study on the incidence of very mild traumatic brain injuries in school rugby. Rugby is considered as one of the most physical sports played (Milburn, 1993). The game is popularly known for skills like tackling, scrumming, rucking and mauling and line-out play. These phases of play are associated with eccentric forces which common lead to soft-tissue contusions, joint sprains, fractures, dislocations, lacerations, grazes and head or spinal injuries (Milburn, 1993).

The incidence of vMTBI and MTBI in this study was high for the rugby season lasting for five months of contact play (372 player hours - match and practice sessions). These players suffered a total of 726 vMTBI and 18 MTBI in the rugby season. The overall incidence was 1951 vMTBI per 1000 player hours and 48 MTBI per 1000 player hours throughout the rugby season in this specific secondary school rugby team.

The ages of the participating groups are shown in Table 3.1 as follows: the total participants in each group (N), the average age and a standard deviation (SD). The average age was 17.4 years.

<u>Table 3.1:</u> The descriptive information on the age of the rugby players

Groups	**N**	**Average age**	**SD**
Group 1	26	17.3	0.68
Group 2	9	17.1	0.60
Group 3	10	17.8	0.63
All 3 Groups	45	17.4	0.68

Group 1 = vMTBI, Group 2 = MTBI & Group 3 = Control Group

The phases of play were divided into the following (Table 3.2): the loose scrum consisting of rucks and mauls, the tackle consisting of being tackled and tackling the opponent, open play described as the phase where the players drive with the ball, not yet a ruck or a maul, the scrum, the line-out and other play consisting of foul play and any other situation of the game.

Table 3.2: The incidence of very mild and mild traumatic brain injuries in the different phases of play in rugby

Phase of play	vMTBI incidence (%)*	MTBI incidence (%)*
Loose scrum (Ruck/Maul)	40	39
Tackles	32	61
Open play	14	0
Scrum	9	0
Line-out	4	0
Other	1	0

* Corrected for unequal numbers in the different positions by doubling the number of sub-concussive injuries in the positions in which there is only 1 player per team and then expressing them as a corrected percentage.

The vMTBI in the different phases of play had an incidence of 40% in the loose scrum phase, 32% in the tackle phase and 14% in the open play phase. The MTBI had an incidence of 61% in the tackle phase and an incidence of 39% in the loose scrum phase. Previous studies also reported a high incidence of MTBI mostly in the tackled phase and the loose scrum phase (Targett, 1998).

These phases are therefore regarded as carrying the greatest risk (for any injury) in rugby. It may be concluded from this study and previous data that schoolboy rugby players may use their head in the wrong position when tackling an opponent, or when going into a loose scrum (Cantu, 1996). This problem could be corrected by improving coaching techniques.

Table 3.3 shows the incidence of vMTBI and MTBI in the different playing positions of the team analysed.

Table 3.3: The incidence of very mild and mild traumatic brain injuries in the different playing positions in rugby

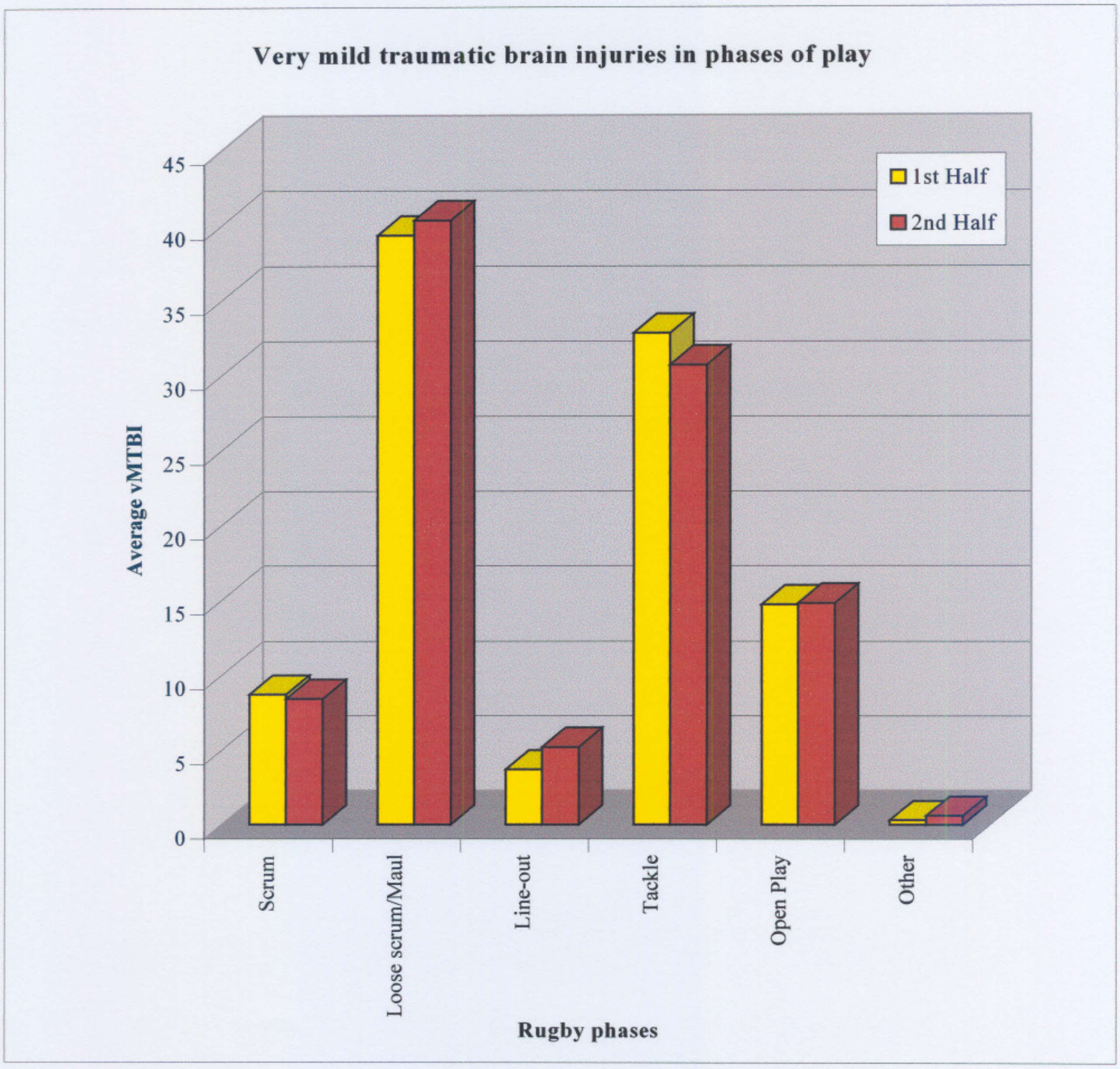
Playing Position	vMTBI incidence (%)*	MTBI incidence (%)*
Eighth man	24	0
Fullback	16	11
Lock	14	11
Hooker	13	0
Scrum-half	11	0
Flanker	6	39
Prop	6	5
Wing	6	17
Center	2	17
Fly-half	2	0

* Corrected for unequal numbers in the different positions by doubling the number of sub-concussive blows in the positions in which there is only 1 player per team and then expressing them as a corrected percentage.

The incidences of vMTBI in the different playing positions were 24% in the eighth man, 16% in the fullback, 14% in the locks, 13% in the hooker and 11% in the scrumhalf. In comparison the incidence of MTBI in the flankers was 39%, in the wings 17% and in the centers 17%. In a previous study it was also found that the incidence of MTBI was the highest in the eighth man, followed by the full back and the locks (Targett, 1998). A possible reason is that the contact situation in rugby is more likely to affect the forwards because of the nature of the game. Better techniques associated with contact situations could be considered to decrease possible traumatic brain injuries. For example, not using the head to make contact, but using the side of the upper body to make contact with the opponent.

The incidence of vMTBI was the highest in the loose scrum and the tackle phase throughout the season in the 1st half and the 2nd half of the rugby matches played as shown in Figure 3.1. A previous study marked that the tackle phase appears to be associated as the phase with the greatest risk of injury overall (Garraway & Macleod, 1995).

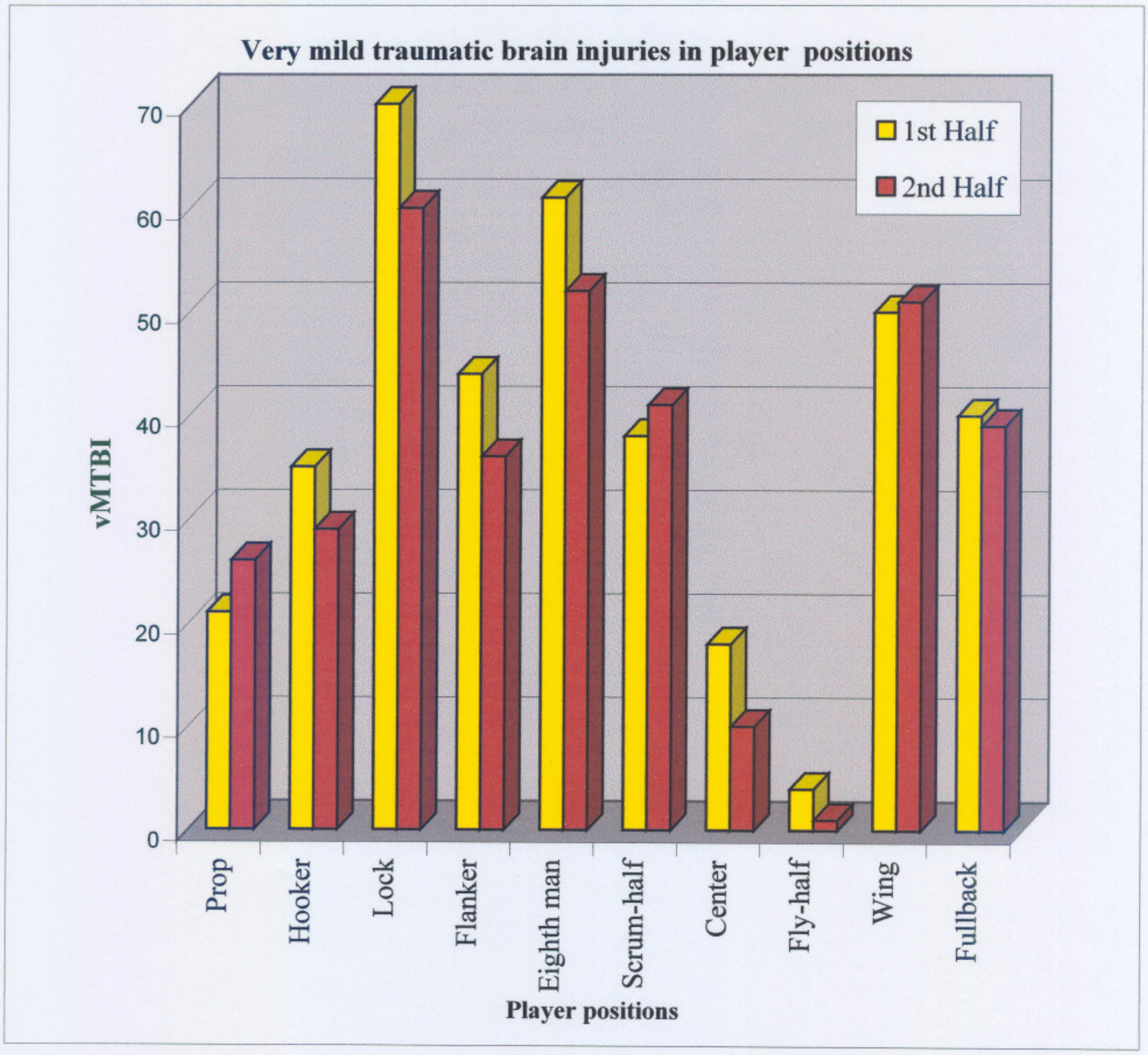
Figure 3.1: The incidence of very mild traumatic brain injuries during the 1st and 2nd half of the rugby matches in the different phases of play



According to Roux *et al.* (1987) the majority of injuries occur in the tackling phase, which suggested that speed is an important component of injury risk, including in vMTBI.

The incidence of vMTBI was the highest in the locks (130 injuries), eighth man (113 injuries) and wings (101 injuries) throughout the season in the 1st half and the 2nd half as shown in Figure 3.2.

Figure 3.2: The incidence of very mild traumatic brain injuries in the 1st and 2nd half in the different player positions in rugby



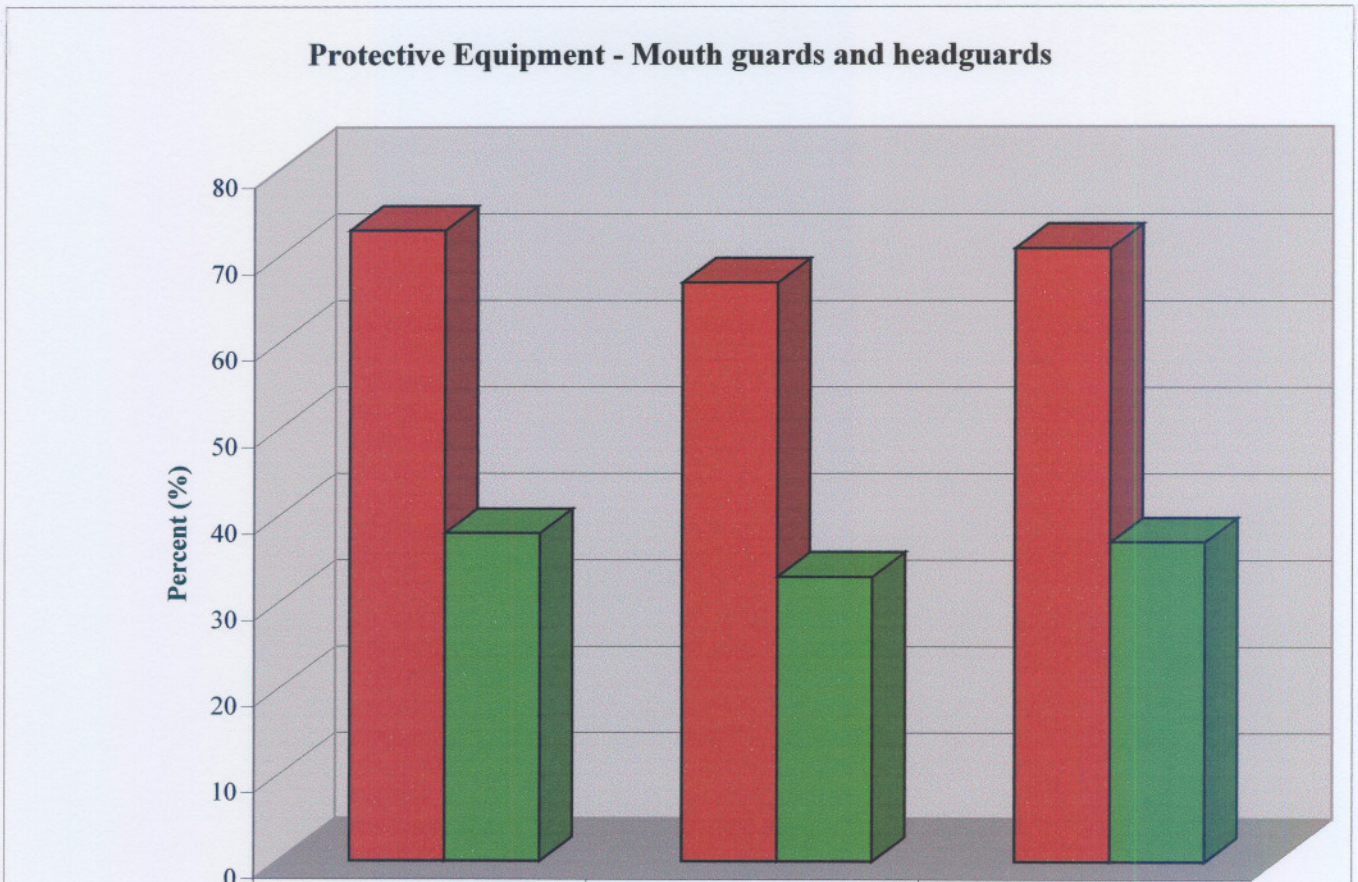
Two observations can be made regarding vMTBI incidence and playing positions in this study. Firstly, the front row forwards (props and hookers) suffered the least vMTBI and, of the back-line positions, the fly half and centers sustained the least vMTBI. In contrast, players in positions involved in the phases of the game in which play is fast and more open (all the back line players except the fly half and centers; and the flankers, eighth man and locks) suffered the most vMTBI.

Secondly, there was a clear indication that the forwards sustained more vMTBI than the back line. The likely explanation for this is that the forwards play a more physical role and sustain vMTBI more in the loose scrum situation, whereas the back line only on occasions is in physical contact in a game of rugby. The back line's vMTBI is more likely to be sustained when tackling an opposing back at speed or when joining the line at speed and then being tackled.

In Figure 3.3 the use of mouth guards and headgear is shown. Mouth guards were used by 71% of all the rugby players in this study (73% with vMTBI and 67% with MTBI). The headguards were used by 37% in total (38% with vMTBI and 33% with MTBI). In this study it seems that the protective headguards were of greater value to protect and prevent vMTBI and MTBI, and lacerations than the mouth guards.

Emphasis on the wearing of protective gear should be even greater at school level. Protective headguards are worn by players in a number of contact sports, both to reduce the severity or likelihood of injury to the head and to prevent re-injury to an athlete (CASM Concussion Committee, 2000). The role of protective headguards is to attenuate the forces of impact, to reduce the acceleration at the point of impact, to distribute the force over a larger area and to protect the soft tissue and bone from surface abrasions caused by frictional forces (Wilson, 1998).

Figure 3.3: The percentage of mouth guards and headguards used in both the very mild and mild traumatic brain injury groups



	Group 1 (Yes)	Group 2 (Yes)	Total (Yes)
Mouth guards	73	67	71
Headguards	38	33	37

There are relatively few methods by which MTBI or vMTBI may be minimised in sport, especially in rugby. Rule changes and rule enforcement may play a role in reducing and preventing concussions (Aubry *et al.*, 2002).

Where a clear-cut mechanism for a certain injury is implicated in a particular sport, the consideration of a rule change needs to be taken. Examples are the rule changes that were made to ban spear tackles, tackling above shoulder height and tackling with a straight stiff arm, therefore reducing the incidence of possible catastrophic head and neck injuries (Gibbs, 1993; Finch *et al.*, 2001). A critical aspect that needs to be taken seriously is emphasis on rule enforcement (Johnston, McCrory, Mohtadi & Meeuwisse, 2001). Sport in general would be much safer if the rules were strictly and correctly enforced. Referees and linesmen should have sufficient training to enforce and interpret the rules correctly and consistently. This may further reduce the rate of injuries, especially head and neck injuries (Herring, Bergfeld, Boland, Boyajian-O'Neill, Cantu, Hersman, Indelicato, Jaffe, Kibler, Mckeag, Pallay & Putukian, 2005)

Protective equipment may also be a method to minimise the number and seriousness of injuries (Wekesa, Asembo & Njororai, 1996).

Headguards acts to protect the wearer from contact injuries such as lacerations or skull fractures and focal and diffuse injuries to the neural tissues, which may result in MTBI. Definite facts on the wearing of headgear to prevent MTBI remain controversial (Wilson, 1998; Pettersen, 2002). A mouth guard that is properly fitted helps prevent orofacial and dental injuries and decreases the impact of a blow against the jaw, which may indirectly help to prevent MTBI (Gibbs, 1993). Although there is still controversy about whether headguards and mouth guards help to prevent MTBI or not (Gibbs, 1993; Wilson, 1998; Pettersen, 2002), they should be encouraged because of the relative high risk of injury during a rugby game. In this study, 37% of the players played with headguards and 71% played with mouth guards, still not appropriate to reduce all types of head and facial injuries in school rugby.

Physical conditioning is important not only to prevent injuries but also to perform at one's best in a specific sport (Cantu, 1992; Rotem & Davidson, 2001). Coaches should emphasise that general fitness is the basis for all sport participation and that pre-seasonal training should be encouraged (strengthening, stretching and cardiovascular exercises) (Rotem & Davidson, 2001). Fitness exercises (speed, agility, power and endurance) should be included in training sessions as well as the enhancement of specific skills required for a certain sport (Rotem & Davidson, 2001). Physical conditioning, especially to the neck and shoulder muscles, could be of value to reduce impact forces transmitted to the brain and can be enhanced by resistance training.

Another important aspect of prevention is the education of team health professionals (Physicians, Physiotherapists, Biokineticist) and coaches towards the recognition of very mild and mild traumatic brain injuries, the seriousness of such an injury and the consequences it could have if inappropriate care is taken (Johnston *et al.*, 2001). Health professionals must take steps to improve their knowledge and understanding of the organised sport environment as well as the risk factors and safety factors inherent to this type of sport participation (Cantu, 1992). Physicians should monitor the health and safety of children involved in organised sport whenever possible, in particular those involved in collision sport (Cantu, 1992). Coaches, the participants and healthcare providers should participate in special programmes of education regarding the detection of MTBI and vMTBI, its clinical features, assessment techniques and principles of safe return to play (Cantu, 1992; Aubry *et al.*, 2002).

They should have credentials that encompass the techniques and skills of youth sport, the specific safety risks of children's sport, the psychology and sociology of children and adolescents and the physiology of growth and development as it relates to physical activity during childhood and adolescence as well as common medically related issues (Micheli *et al.*, 2000).

3.4 CONCLUSION

There is a lack of research concerning the incidence and consequences of very mild and mild traumatic brain injuries in rugby. This study has shown a high incidence of vMTBI in a cohort of secondary school rugby players in one season.

This study's high incidence of vMTBI and MTBI provides information that may lead to future rule changes or play techniques, so that school rugby players may enjoy a safer contact sport.

The short and long-term effects of repetitive vMTBI in school rugby players are unknown. The high incidence of vMTBI and MTBI in schoolboy rugby as shown in this study could have a life changing effect if not detected or correctly managed. It could possibly have the effect of the so-called punch-drunk syndrome (Roberts, 1992). Further in depth research is necessary to determine the short and long-term effects of neuropsychological and academic consequences of these type of injuries in schoolboy rugby.

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CHAPTER 4

A comparison of the neuropsychological status of secondary school rugby players suffering from very mild (vMTBI) and mild (MTBI) traumatic brain injury with a healthy sedentary control group

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A COMPARISON OF THE NEUROPSYCHOLOGICAL STATUS OF SECONDARY SCHOOL RUGBY PLAYERS SUFFERING FROM VERY MILD (vMTBI) AND MILD (MTBI) TRAUMATIC BRAIN INJURY WITH A HEALTHY SEDENTARY CONTROL GROUP

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Abstract

Objective ***- Information on the consequences of MTBI on secondary school rugby players are well documented, but information on the consequences of repetitive sub-concussive injuries or so-called very mild traumatic brain injuries (vMTBI) is lacking. The aim of this study was to compare the neuropsychological status of a team of secondary school rugby players with very mild traumatic brain injuries and mild traumatic brain injuries and a sedentary control group.***

Methods ***– In this study thirty-five (35) secondary school rugby players were divided into a sub-concussive (vMTBI) group (group1) (n=26) and a concussive (MTBI) group (group2) (n=9) at the end of a season. Ten (10) secondary school non-rugby players were selected as a control group (group 3). The control group consisted of schoolboys from the same school who did not participate in any contact sport. Pre-season baseline and post-season pen and paper neuropsychological tests (SAC, Colour Trial Test (CTT) 1 and 2, Digit Symbol Modalities Test (DSMT) and Wechsler Memory Scale-Revised (WMS-R) Test for verbal, visual, general, delayed memory and attention/concentration) were conducted on the 3 groups.***

Results ***– A Statistically significant ($p \leq 0.05$) difference was found in the WMS-R: Delayed memory ($p=0.01$) between the baseline and post-season score of the very mild traumatic brain injury (vMTBI) group. Statistically significant differences were also found in the DSMT ($p=0.02$) between the baseline score of the vMTBI group and the post-season score of the control group and WMS-R: Visual memory ($p=0.03$) between the baseline score of the vMTBI group and the post-season score of the mild traumatic brain injury (MTBI) group.***

Note: In this study, the term mild traumatic brain injuries (MTBI) refers to the term concussion and the term very mild traumatic brain injuries (vMTBI) refers to the term sub-concussive injuries and will be used interchangeably throughout this study. Group 1 = vMTBI, Group 2 = MTBI & Group 3 = Control group.

Statistically significant ($p \leq 0.05$) decrease in the SAC test totals between both the vMTBI and MTBI groups were documented in the different games throughout the rugby season when compared with the baseline test. No statistically significant differences ($p \leq 0.05$) between the pre-season and post-season's scores of the SAC test totals were documented.
Conclusion – The findings of this study indicate a statistically significant difference ($p=0.01$) in delayed memory of the vMTBI rugby players. This is the first evidence of possible neurocognitive deficits towards delayed memory in vMTBI at secondary school level. A multi-centred prospective study, ensuring a large enough sample size and more neuropsychological data is necessary to evaluate these findings further.

Keywords: Concussion; Neuropsychological tests; Rugby; Sub-concussive injuries; Traumatic brain injuries.

4.1 INTRODUCTION

Rugby is one of South Africa's most popular sports, starting at school level and continuing up to professional and national levels (Shuttleworth-Jordan *et al.*, 1993; Calligaro *et al.*, 2002).

Mild traumatic brain injuries (MTBI) or concussion as used interchangeably in the literature (Maroon *et al.,* 2000; Wills & Leathem, 2001) are an important public health concern due to the high incidence and frequently persisting symptomatology (Evans, 1992).

The term concussion enables the use of an additional description within the spectrum of mild traumatic brain injuries, namely sub-concussive injuries that are explained in the literature as involving subtle changes in consciousness, difficult to detect with symptoms usually lasting seconds to minutes (De Villiers, 1987), therefore a very mild traumatic brain injury (vMTBI).

Note: In this study, the term mild traumatic brain injuries (MTBI) refers to the term concussion and the term very mild traumatic brain injuries (vMTBI) refers to the term sub-concussive injuries and will be used interchangeably throughout this study. Group 1 = vMTBI, Group 2 = MTBI & Group 3 = Control group.

A sub-concussive injury or very mild traumatic brain injury may be defined as an apparent brain insult with insufficient force to cause hallmark symptoms of concussion (Jordan, 2000; Webbe & Bath, 2003).

The concussion literature has focused mainly on the evaluation and management of sports participants who suffer a mild traumatic brain injury (McCrea *et al.,* 1998; Matser *et al.,* 1999). More concern is the potential harm from head injuries experienced by children or adolescents at the minor league levels of sport (McCrea *et al.,* 1997; Delayney & Drummond, 1999). The use of clinical tests as part of diagnostic protocol of mild traumatic brain injuries has also been established and incorporated during sideline assessment and in making of return to play decisions (McCrea *et al.,* 1998).

Neuropsychological tests are now commonly used to provide an objective measure of cognitive function and recovery after a vMTBI or MTBI. Given that individuals vary considerably in their performance on many neuropsychological tests, interpretation of the results after MTBI and vMTBI is facilitated by knowledge of the baseline scores for each player (Aubry *et al.*, 2002; McCrory *et al.*, 2004).

Very few circumstances allow pre-injury and post-injury measures of cognitive functioning in a mild traumatic brain injured person (Torg *et al.*, 1998). Contact sport provides such opportunities with vMTBI and MTBI being most common in high-impact sport, such as rugby (Cantu, 1998; Matser *et al.,* 2000). For this reason, a MTBI in organised sport has become the focus of intense attention from medical and neuropsychological professions, sport organisations and the media (Davis & Mckelvey, 1998).

McCrea *et al.* (1997) designed the Standardised Assessment of Concussion (SAC), which has been adopted as the abbreviated sideline neurological examination (Asthagiri *et al.*, 2003). Although the SAC does not replace a thorough neurological and formal neuropsychological evaluation, it has proven to be a sensitive and specific means of immediately detecting even mild grades of MTBI in the absence of observable neurological signs of injury and is a gross predictor of post MTBI (McCrea *et al.*, 1997).

In 2004 in Prague, the 2nd International Conference on Concussion in Sport updated and created a standardised tool, the *Sport Concussion Assessment Tool* (SCAT), which guides and educates athletes and assists with the assessment of sport concussion (McCrory *et al.*, 2004). The sideline evaluation includes signs and symptoms, memory, concentration/attention, neurologic and return to play screening (McCrory *et al.*, 2004). The following tools were combined to develop the SCAT (McCrory *et al.*, 2004): the sideline evaluation for concussion (McCrea *et al.*, 1997; McCrea *et al.*, 1998), the management of concussion sport palm card (Kelly & Rosenberg, 1997), the Standardised Assessment of Concussion (SAC) (McCrea *et at.*, 2000), the sideline concussion check, the McGill Abbreviated Concussion Evaluation (ACE) [unpublished], the National Hockey League Physician Form [unpublished], the UK Jockey Club assessment of concussion (Turner, 1998) and the Maddocks questions (Maddocks *et al.*, 1995).

The SCAT was evaluated for face and content validity on the basis of scientific literature and clinical experience of the professionals involved at the Prague Conference (McCrory *et al.*, 2004).

Ideally, a more comprehensive neuropsychological evaluation should be incorporated after a MTBI or a vMTBI is suspected. Neuropsychological testing enables the clinician to follow a given athlete's deficits (cognitive, memory, and visual) objectively following a vMTBI or MTBI. In general, improvement in test results occurs as the head injury resolves. The availability of a baseline, pre-season test is now especially useful for longitudinal follow-up. The value of neuropsychological testing has been illustrated at many levels of competition (including secondary school) in different sport (Matser *et al.,* 1998; Collins *et al.,* 1999; Lovell & Collins, 1999).

Only in the past few decades has there been interest in studying the neuropsychological consequences of concussion. A range of neuropsychological deficits has been reported after MTBI, which includes *inter alia,* disturbances of new learning and memory, planning and the ability to switch mental 'set', and reduced attention and speed of information processing (Lezak, 1995). Neuropsychological testing enables more accurate assessment of MTBI and better decision making for return to play (McCrory, 1997; Maroon *et al.*, 2000).

It has been shown that cognitive recovery may precede or follow resolution of clinical symptoms, suggesting that the assessment of cognitive function should be an important component in any return to play protocol (Aubry *et al.*, 2002). In the consideration of injury recovery or return to play, such test strategies must access the cognitive domains of information processing, planning, memory and switching mental set.

Numerous paradigms are in current use. Examples of these include paper and pencil tests (McGill ACE, SAC, SCAT), condensed batteries (McGill ACE), comprehensive protocols administered by neuro psychologists (NHL, Australian football) and computerised test platforms – for example, IMPACT, CogSport, ANAM, Headminders (Aubry *et al.*, 2002).

The first computerised neuropsychological test batteries were developed in 1998 specifically for use with athletes (Blieberg *et al*, 1998). This computerised neuropsychological test was called the Immediate Measurement of Performance and Cognitive Testing (IMPACT). The test battery was designed to evaluate multiple aspects of neuropsychological functioning among athletes, including attention span, sustained and selective attention, reaction time and several dimensions of memory (Maroon *et al.*, 2000).

Recent work with computerised platforms suggests that performance variability may be a key measure for diagnosis of acute MTBI, even in the absence of a baseline test.

Inherent problems with most neuropsychological tests include the normal ranges, sensitivity and specificity of tests, and practice or learning effect, as well as the observation that players may return to baseline while still symptomatic (Grindel *et al.,* 2001). In part, these may be a problem of the currently available pen and paper tests. Computerised testing using infinitely variable test paradigms may overcome these concerns. Computerised testing also has the logistical advantage that the team doctor may administer the test or is web based rather than having to employ a neuro psychologist for a formal assessment (Aubry *et al.*, 2002). Another advantage that computerised tests have over pen and paper tests is that it allows detecting subtle impairments such as those expected in mildly concussed athletes (Collie *et al.*, 2001). These include randomised stimulus presentation, typically high-retest reliability, lack of floor and ceiling effects and the ability to assess a range of cognitive domains in a short period of time (Collie *et al.*, 2001).

Individual players vary with respect to their levels of performance on tests of mental processing speed, attention/concentration, memory and motor speed (Maroon *et al.,* 2000). Therefore, pre-season baseline testing of athletes is essential. Without the knowledge of a baseline score of each athlete before a vMTBI or MTBI, it is difficult to assess whether any deficits detected during testing are attributable to the effects of the vMTBI or MTBI or to other unrelated factors. When an athlete sustains a vMTBI or MTBI, return to play can be determined by guidelines and neuropsychological tests.

Neuropsychological testing is one of the cornerstones of MTBI evaluation and contributes significantly to both understanding of the injury and management of the individual. To maximise the clinical utility of such neuropsychological assessment, baseline testing is recommended (Aubry *et al.*, 2002). It must be emphasized, however, that neuropsychological assessment should not be the sole basis of a return to play decision, but rather be seen as an aid to the clinical decision-making.

Without pre-seasonal neuropsychological data of each player, it is difficult to assess the clinical relevance of the test results. Pre-injury learning disabilities, attention deficit disorders and other factors such as test anxiety, may affect performance on more demanding tests (Maroon *et al.*, 2000). It is, therefore, necessary to obtain appropriate histories regarding previous MTBI and their severity, so that this information can be integrated with the results of pre-season testing of the rugby players (Maroon *et al.*, 2000).

The aim of this study is to investigate the neuropsychological status and consequences of MTBI and vMTBI on secondary school rugby players when compared pre-season and post-season and with a non-injured and aged matched sedentary control group.

4.2 MATERIALS AND METHODS

4.2.1. Selection of research group

The study group consisted of thirty-five (35) rugby players (group 1 = vMTBI and group 2 = MTBI) from a secondary school's first (n=15) and second (n=15) team and reserve players (n=5) playing for the third team and ten (n=10) non-rugby players as a control (group 3). The control group consisted of schoolboys not participating in any contact sport. The control group was randomly selected from the same school where the rugby players were selected and matched for age, gender and education level. Persons with diagnosed learning disabilities, previous concussions, epilepsy and drug abuse were not considered for the control group of this study. All the participants, parents or guardians gave informed consent for participating in this study. The Ethics Committee of the North-West University approved the study.

4.2.2. Measuring instruments

Baseline and post-seasonal neuropsychological assessment

Pre-season and post-season neuropsychological tests (CTT, SDMT, WMS-R and the SAC) were completed on the research group and the control group by qualified clinical psychologist interns. After each match played throughout the season the research group also completed a SAC test. The rugby season was approximately five months long. Individual players vary with respect to their levels of performance on tests of memory, attention/concentration, mental processing speed and motor speed. The following neuropsychological tests were used in this study.

4.2.2.1 The Symbol Digit Modalities Test (SDMT) (Smith, 1982)

The SDMT consists of eight rows containing in all 110 small blank squares, each paired with a randomly assigned symbol that will be compared with a number from one to nine, to test the subject's concentration and visual memory ability. Above these rows is a printed key that pairs each number with a different non-sense symbol. Following a practice trial on the first ten squares, the task is to fill in the blank spaces with the number that is paired to the symbol above the blank space as quickly as possible for 90 seconds. The score is the number of squares filled in correctly (Smith, 1982). See **Appendix A** for the Digit Symbol Modalities Test.

4.2.2.2. The Colour Trial Test (CTT) (Maj *et al.*, 1993)

In Colour Trial Test-1 subjects are given a page with scattered circles numbered from one to 25, with even-numbered circles coloured yellow (Y) and the odd-numbered ones coloured pink (P). The task requires the subject to draw a line following the number sequence. Colour Trial Test-2 also presents the subject with a page containing 25 circles, but on this sheet each colour set is numbered to 13 for the yellow odd numbers and to 12 for the pink even ones.

The task is to follow the number series with a pencil by alternating between the two colours as well (1Y-1P-2Y etc.) The CTT is used to test the subject's concentration and visual memory ability. See **Appendix A** for the Colour Trial Test-1 and Test-2.

4.2.2.3. Wechsler Memory Scale–Revised (WMS-R) (Wechsler, 1987)

The Wechsler Memory Scale-Revised comprises a series of brief subtests, each measuring a different facet of memory (Wechsler, 1987). See **Appendix A** for the Wechsler Memory Scale–Revised (WMS-R) test. The following subtests with their different measuring facets were used:

- *Information and Orientation Questions*

  This subtest contains simple questions covering biographical data, orientation and common information from long-term memory. Questions 1 to 7 requested the examinee's name and other relative information. Questions 8 to 14 concerned the individual's orientation in time (date, time of day) and place (locality, place of testing). The last two questions concerned the individual's hand preference and whether he or she has any impairments of hearing or vision that could influence performance on some of the WMS-R subtests (Wechsler, 1987).

- *Mental control*

  The three items of this subtest are, counting backward from 20 to 1 recording the time in seconds. The time limit is 30 seconds. Name the letters of the alphabet and record the time in seconds. The time limit is 30 seconds. Counting in 3's, record the time in seconds. The time limit is 45 seconds (Wechsler, 1987). This subtest will test the subject's memory and concentration levels.

- *Figural memory*

  This subtest measures memory for figural stimuli. Figural memory involves showing the examinee a set of abstract designs. Then, after each set of designs is removed, the examinee is asked to identify the designs within a larger set of designs (Wechsler, 1987).

- *Logical memory I (Immediate recall)*

  This subtest consists of two brief stories that are read to the examinee. After each story, the examinee retells the story from memory (Wechsler, 1987).

- *Visual paired associates I (Immediate recall)*

  This subtest requires the examinee to learn the colour associated with each of six abstract line drawings. In order to minimise the role of verbal mediation in memorising and responding to the figure-colour pairs, the colour names are not used either in presenting the items or in responding to them. The pairs are presented until the examinee answers all six items correctly, however, only the first three presentations are scored and no more than six presentations are given. Using six presentations insures that the examinees learn the material to the criterion of one perfect repetition (Wechsler, 1987).

- *Verbal paired associates I (Immediate recall)*

  In this subtest a group of eight word pairs are read to the examinee, then the first word of each pair is read and the examinee is asked to supply the second word from memory. Only the first three presentations are scored, although six presentations are given (Wechsler, 1987).

- *Visual reproduction I (Immediate recall)*

  The examinee looks at a geometric design and is then asked to draw it from memory (Wechsler, 1987).

- *Digit span*

  The two parts of the Digit Span subtest, 'Digits Forward' and 'Digits Backward', are administered separately. On 'Digits Forward', number sequences of increasing length are read to the examinee. After each sequence the examinee is asked to repeat them from memory. On 'Digits Backward', similar number sequences are read to the examinee and after each sequence the examinee is asked to repeat them backwards. Administer 'Digits Backward' even if the examinee does poorly on 'Digits Forward' (Wechsler, 1987).

- *Visual Memory Span*

  The two parts of the Visual Memory Span subtest, Tapping Forward and Tapping Backward are administered separately. In Tapping Forward the examinee watches the examiner touch the red squares on Card 1 in sequences of increasing length, and after each sequence is asked to repeat the performance from memory. In Tapping Backward the examinee watches the examiner touch the green squares on Card 2 in sequences of increasing length, and is asked to repeat the performance in reverse. Administer Tapping Backward even if the examinee does poorly on Tapping Forward (Wechsler, 1987).

- *Logical Memory II (Delayed recall)*

  This subtest was administered at least 30 minutes after completion of Logical Memory I. If necessary, pause after Visual Memory Span to ensure that at least 30 minutes have elapsed (Wechsler, 1987).

- *Visual Paired Associates II (Delayed recall)*

  This subtest was administered at least 30 minutes after completion of Visual Paired Associates I (Wechsler, 1987).

- *Verbal Paired Associates II (Delayed recall)*

  This subtest was administered at least 30 minutes after completion of Verbal Paired Associates I (Wechsler, 1987).

- *Visual Reproduction II (Delayed recall)*

  This subtest was administered at least 30 minutes after completion of Visual Reproduction I (Wechsler, 1987).

4.2.2.4. Standardised Assessment of Concussion (SAC) (McCrea *et al.*, 1998)

The Standardised Assessment of Concussion (SAC) is a brief screening instrument designed for the neurocognitive assessment of concussion. This assessment can be used by a non-neuropsychologist that has no prior expertise in psychometric testing to test subjects. The SAC requires approximately five minutes for assessment of four domains of cognition, including orientation, immediate memory, concentration and delayed recall, summing to a total composite score of 30 points. Three equivalent alternate forms of the test will be used in this study to minimise practice effects from repeated administration (McCrea *et al.*, 1998). See **Appendix A** for the Standardised Assessment of Concussion (SAC) test.

Neuropsychological testing represents the most sensitive and practical method available for delineating cognitive and neurobehavioural events associated with MTBI, and involves the application of neuropsychological test instruments that are sensitive even to subtle changes in attention, concentration, memory, information processing and motor speed or co-ordination (Lezak, 1995), which could be detected in vMTBI. All these neuropsychological tests (CTT, SDMT, WMS-R and the SAC) used in this study have been used extensively in other studies (McCrea *et al.*, 1998; Collins *et al.*, 1999; Lovell & Collins, 1999) and comply with scientific criteria regarding to validity and reliability.

4.2.3. Statistical analysis

The programme STATISTICA (version 7.0, Stat soft, Tulsa, OK) was used to analyse the data and divide it into the following statistical analysis. Descriptive statistics were used on each group to obtain the means and standard deviation on the neuropsychological tests (SAC, CTT 1, CTT 2, DSMT, WMS-R) as shown in Table 4.2. One-way ANOVA's were used to compare the different group's performance in the neuropsychological battery of tests. One way Post-hoc Tuckey HSD analysis was applied to examine significant differences ($p \leq 0.05$) between pairs of means in each group's baseline and post-season results of the entire neuropsychological test battery.

4.3 RESULTS

The mean score on each neuropsychological test (except the SAC test) is based on a *Z* score to classify the ability level of the subjects as shown in Table 4.1.

<u>Table 4.1:</u> Classification of ability levels (Lezak, 1995)

Classification	***Z*-Score**
Very superior	+2.0 and above
Superior	+1.3 to 2.0
High average	+0.6 to 1.3
Average	+0.6 to –0.6
Low average	-0.6 to -1.3
Borderline	-1.3 to –2.0
Retarded	-2.0 and below

Table 4.2 reports the descriptive information on the neuropsychological test used in this study. The *Z* score on CTT1 and CTT2 are reversed (for instance a score of -0.70 is normally classified as low average, but in the CTT tests it is classified as high average). No statistical significant differences ($p \leq 0.05$) were found in the SAC baseline and post-season scores. No statistical significant results were documented on the CTT 1 and CTT 2 test.

A statistically significant difference ($p=0.02$) in the DSMT was observed between the very mild traumatic brain injury group's baseline score and the control group's post-season score.

Table 4.2: Descriptive information on the neuropsychological tests completed

Variable	Group	N	Mean	SD	p value
SAC: Orientation Baseline testing	1	26	4.8	0.5	a 0.80
	2	9	5.0	0.0	b 0.99
	3	10	4.9	0.3	c 0.99
SAC: Orientation Post-season testing	1	26	4.7	0.5	d 0.99
	2	9	4.8	0.3	e 0.99
	3	10	4.9	0.3	f 0.77
SAC: Immediate Memory Baseline testing	1	26	12.5	2.1	a 0.17
	2	9	14.3	1.4	b 0.99
	3	10	12.3	2.2	c 0.96
SAC: Immediate Memory Post-season testing	1	26	13.5	2.2	d 0.99
	2	9	13.1	1.8	e 0.99
	3	10	12.7	2.1	f 0.96
SAC: Concentration Baseline testing	1	26	3.8	1.0	a 0.99
	2	9	3.2	1.4	b 1.00
	3	10	3.8	1.2	c 0.99
SAC: Concentration Post-season testing	1	26	3.8	1.2	d 1.00
	2	9	3.7	1.1	e 0.99
	3	10	3.5	0.9	f 0.98
SAC: Delayed recall Baseline testing	1	26	3.9	1.1	a 0.70
	2	9	4.6	0.7	b 0.99
	3	10	3.8	0.9	c 0.68
SAC: Delayed recall Post-season testing	1	26	4.3	0.9	d 0.96
	2	9	4.2	1.1	e 1.00
	3	10	3.9	0.7	f 0.86

Variable	Group	N	Mean	SD	p value
SAC: Total	1	26	25	3.4	a 0.33
Baseline testing	2	9	27.1	2.4	b 0.99
	3	10	24.8	3.4	c 0.74
SAC: Total	1	26	26.3	3.5	d 0.97
Post-season testing	2	9	26.0	3.8	e 1.00
	3	10	25.0	3.0	f 0.96
CTT 1	1	26	0.04	1.7	a 0.47
Baseline testing	2	9	-0.13	1.3	b 0.99
	3	10	-0.13	1.1	c 0.66
CTT 1	1	26	-0.5	1.2	d 0.57
Post-season testing	2	9	-0.78	0.7	e 0.25
	3	10	-1.03	0.5	f 0.93
CTT 2	1	26	-0.59	0.6	a 0.11
Baseline testing	2	9	-0.7	0.4	b 0.99
	3	10	-0.7	0.8	c 0.98
CTT 2	1	26	-0.84	0.7	d 0.66
Post-season testing	2	9	-0.95	0.2	e 0.81
	3	10	-0.89	0.4	f 0.99
DSMT	1	26	-0.19	1.3	a 0.14
Baseline testing	2	9	0.39	1.9	b 0.99
	3	10	1.51	1.3	c 0.39
DSMT	1	26	0.75	1.7	d 0.76
Post-season testing	2	9	0.68	2.0	e *0.02*
	3	10	1.89	2.3	f 0.63
WMS-R: Verbal	1	26	0.21	0.7	a 0.53
Baseline testing	2	9	0.19	0.7	b 0.99
	3	10	0.33	0.7	c 0.60

Variable	Group	N	Mean	SD	p value
WMS-R: Verbal Post-season testing	1	26	0.50	0.9	d 0.53
	2	9	0.73	0.9	e 0.39
	3	10	0.77	0.7	f 0.97
WMS-R: Visual Baseline testing	1	26	-0.09	1.0	a 0.75
	2	9	0.43	0.7	b 0.32
	3	10	0.43	0.7	c 0.99
WMS-R: Visual Post-season testing	1	26	0.22	0.9	d *0.03*
	2	9	1.00	1.1	e 0.37
	3	10	0.57	0.7	f 0.92
WMS-R: General Baseline testing	1	26	0.15	0.8	a 0.09
	2	9	0.31	0.6	b 0.99
	3	10	0.40	0.7	c 0.56
WMS-R: General Post-season testing	1	26	0.60	0.9	d 0.28
	2	9	0.82	0.7	e 0.11
	3	10	0.94	0.8	f 0.94
WMS-R: Attention & Concentration Baseline testing	1	26	-0.68	0.7	a 0.40
	2	9	-0.31	0.8	b 0.81
	3	10	-0.10	1.1	c 0.99
WMS-R: Attention & Concentration Post-season testing	1	26	-0.35	0.9	d 0.13
	2	9	0.16	1.0	e 0.68
	3	10	-0.21	0.9	f 0.99
WMS-R: Delayed Baseline testing	1	26	0.62	0.8	a *0.01*
	2	9	0.70	1.0	b 0.64
	3	10	0.80	1.2	c 0.54
WMS-R: Delayed Post-season testing	1	26	-0.08	1.2	d 0.33
	2	9	0.03	0.7	e 0.17
	3	10	0.36	0.9	f 0.99

Group 1 = Sub-concussive injuries
Group 2 = Concussive injuries
Group 3 = Control Group

p value (a) = group 1 baseline vs. group 1 post
p value (c) = group 3 baseline vs. group 3 post
p value (e) = group 1 baseline vs. group 3 post

p value (b) = group 2 baseline vs. group 2 post
p value (d) = group 1 baseline vs. group 2 post
p value (f) = group 2 baseline vs. group 3 post

The WMS-R subtest namely attention or concentration, general memory and verbal memory showed no statistically significant results. A statistically significant difference ($p=0.03$) in the WMS-R: Visual Memory test was observed between the vMTBI group's baseline score and the MTBI group's post-season score. A statistically significant difference ($p=0.01$) was observed in the WMS-R: Delayed Memory test between the vMTBI group's baseline score and its post-season score.

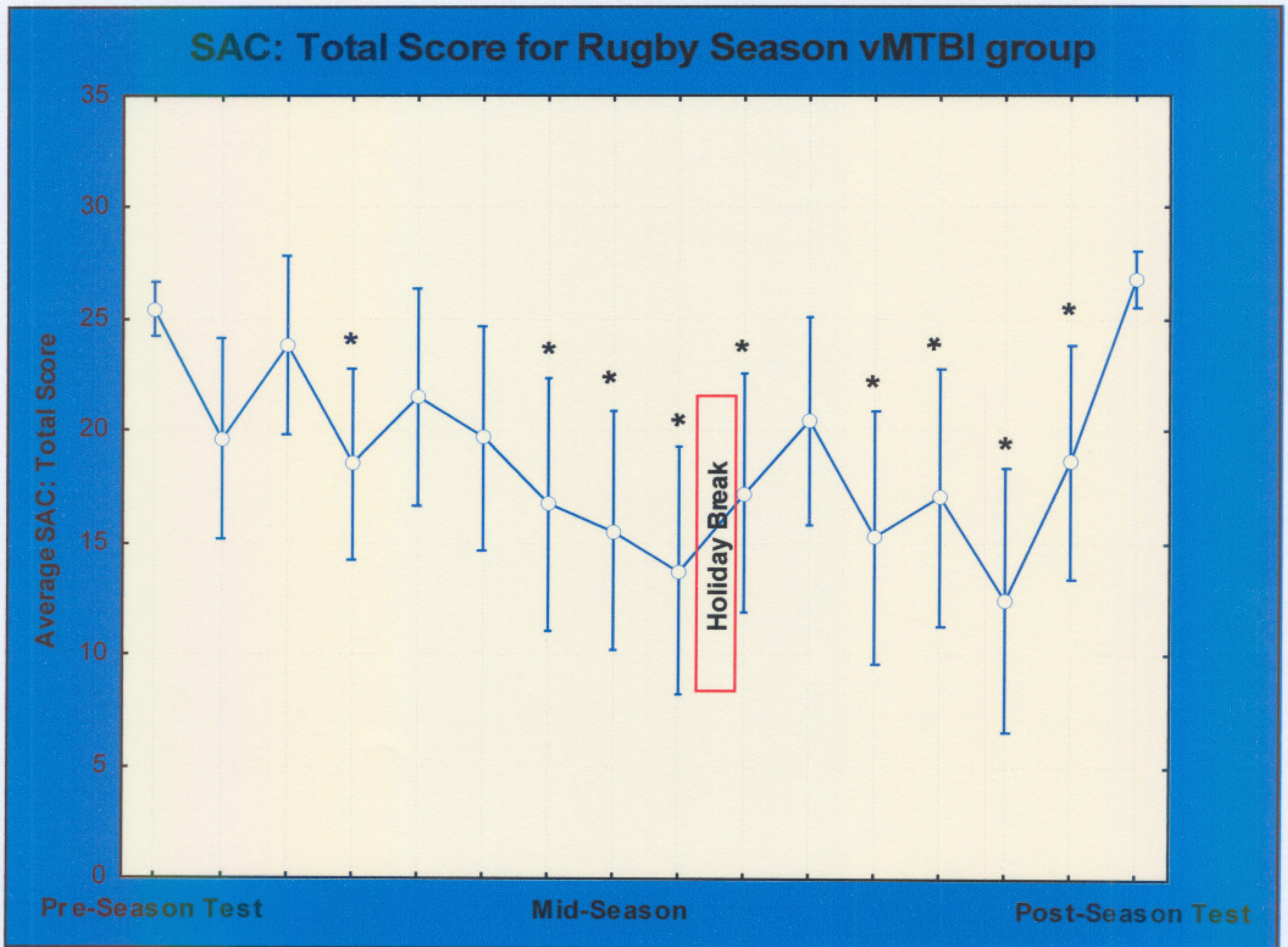
Table 4.3 reports the statistically significant results between the SAC test totals when compared with the baseline test. The statistically significant ($p\leq0.05$) results were obtained in game 7, 8, and 11 in both the vMTBI and MTBI groups, in game 3, 6, 9, 12, 13, 14 in vMTBI group and in game 5 in MTBI group. No statistically significant differences ($p\leq0.05$) between the pre-season and post-season's scores of the SAC test totals were obtained.

Table 4.3: Statistically significant ($p\leq0.05$) results between the SAC test totals during the season when compared with the baseline test

SAC Tests	P-value Group 1	P-value Group 2
Game 1	0.056	0.058
Game 2	0.926	0.227
Game 3	*0.005*	0.056
Game 4	0.246	0.382
Game 5	0.077	*0.016*
Game 6	*0.007*	0.061
Game 7	*0.001*	*0.004*
Game 8	*0.001*	*0.005*
Game 9	*0.030*	0.197
Game 10	0.095	0.724
Game 11	*0.002*	*0.008*
Game 12	*0.039*	0.538
Game 13	*0.001*	0.179
Game 14	*0.027*	0.314
Post-season Test	0.179	0.708

Figure 4.1 and Figure 4.2 report the SAC test total score for the whole rugby season, which shows the downward curve in the score's towards the mid-season. Both the vMTBI and MTBI group's SAC test total scores were low at mid-season time. This could suggest that most of the neurological effects of vMTBI and MTBI took place in the mid-season (approximately game 5 – game 8). The curve then went upward towards the end of the season.

Figure 4.1: The SAC: Total scores of the vMTBI group throughout the rugby season

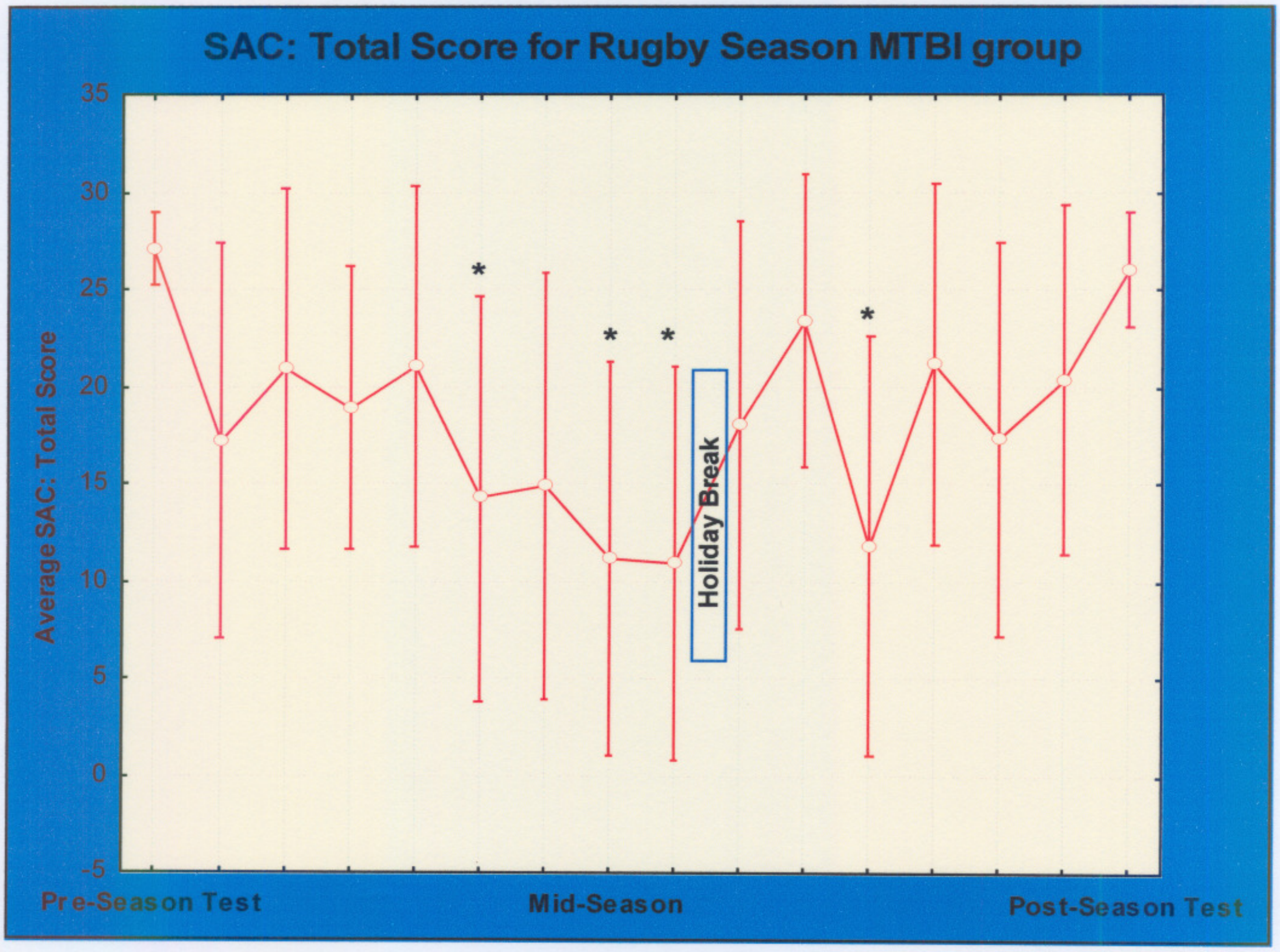


- = $p \leq 0.05$ (Statistically Significant p=value)

The rugby season was played over a period of 5 months. All the matches were played weekly, except when the holiday break came. The holiday break represented 4 weeks. The post-season testing was conducted 2-4 week after the last match.

The explanation for the upward curve after the mid-season could be that of a holiday break (marked on the graph) which took place at that time and may have given enough time to recover from the symptoms associated with MTBI and vMTBI.

Figure 4.2: The SAC: Total scores of the MTBI group throughout the rugby season

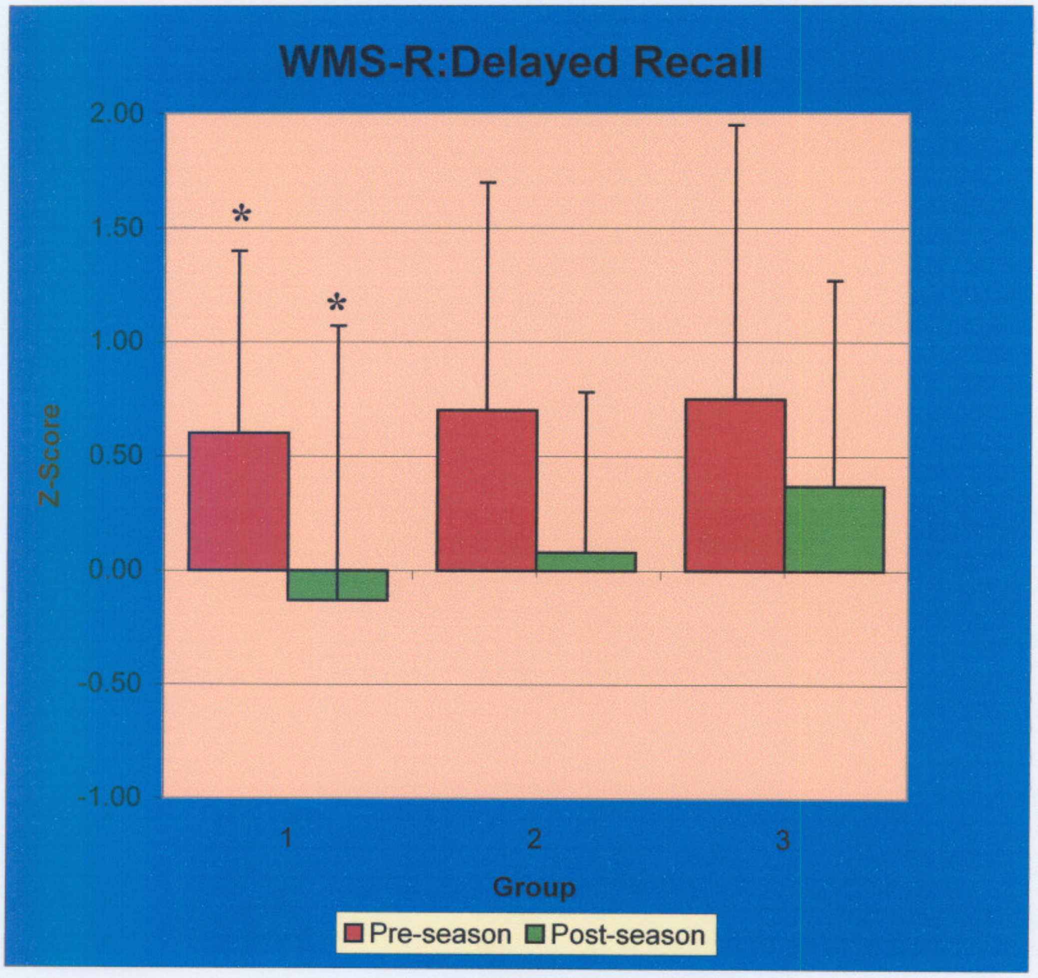


*** = p ≤ 0.05 (Statistically Significant p=value)**

The rugby season was played over a period of 5 months. All the matches were played weekly, except when the holiday break came. The holiday break represented 4 weeks. The post-season testing was conducted 2-4 week after the last match.

The WMS-R: delayed memory pre-season and post-season scores of all three groups are shown in Figure 4.3. A statistically significant difference between the vMTBI group's pre-season and post-season delayed memory scores was found ($p=0.01$). The statistical significance implicated that vMTBI had a negative impact on the vMTBI group's delayed memory.

Figure 4.3: The pre-season and post-season neuropsychological (WMS-R) test for Delayed Recall



* = $p \leq 0.05$ (Statistically Significant p=value)

4.4 DISCUSSION AND CONCLUSION

Sportsmen playing contact sport such as rugby are likely to sustain a number of player-to-player collisions and blows either directly to the head or causing the head to shake. This brings with it the sobering knowledge that the brain is neither capable of regeneration nor, unlike many other body parts and organs, of transplantation (Calligaro *et al.*, 2002).

Many of these injuries are subtle, difficult to detect with symptoms usually lasting seconds to minutes (De Villiers, 1987), therefore a vMTBI. These injuries are frequently and repetitively sustained in contact sport such as rugby, which leads to concern for the potential harm it poses for children or adolescents at the minor league levels of sport (McCrea *et al.*, 1997; Delayney & Drummond, 1999). Currently, there are no return-to-play guidelines for athletes with single or repetitive episodes of vMTBI. There is a possibility that a player with vMTBI or even repetitive vMTBI's may complete a match unnoticed or without being evaluated properly. These injuries may fulfil the diagnostic criteria of MTBI (Aubry *et al.*, 2002), but can easily go unnoticed because of their subtle nature.

The value of neuropsychological testing in determining persistent and continuing cerebral effects of head injuries sustained during athletic endeavours has been illustrated at many levels of competition (including high school, club, collegiate and professional) and across many sports (Asthagiri *et al.*, 2003).

The important factors for succeeding in the implementation of these tests should be taken into consideration and should include the availability of baseline testing, validity of the test battery, problems involving repeated testing, interpretation of the test, costs of testing, presence of severe or prolonged symptoms, presence of multiple concussions, age, gender and perhaps the level of play (Bleiberg *et al.*, 2004; McCrory *et al.*, 2004). It, is therefore, imperative that as much as possible further research and dissemination of information should be gathered, so that every effort may be made to ensure that a responsible balance be maintained between promoting contact sport and protecting the participating athletes (Aubry *et al.*, 2002; Bleiberg *et al.*, 2004; McCrory *et al.*, 2004).

This study showed that there are statistically significant reductions in the SAC test (total score) throughout a single rugby season in the group of players with repetitive vMTBI when compared with the baseline test. The same results were obtained in the SAC test (total score) throughout a single rugby season in the group of players with MTBI when compared with the baseline test. This means that the longer the season is running without proper rest or management of vMTBI and MTBI, the more the symptoms and neuropsychological deficits become visible.

This is the first study to show evidence that both the vMTBI and MTBI have the same outcome in results when the SAC total scores are compared throughout the season. This may help to set more clear criteria for such traumatic brain injuries (vMTBI and MTBI) and to help manage such injuries better in future. The fact that no statistically significant differences ($p \leq 0.05$) between the pre-season and post-season's scores of the SAC test totals were obtained in this study may be the result of the 2-4 week period after the last game was played and the post-season testing. External factors such as school examinations and sickness of participants were the reasons for the 2-4 week delay before post-season testing could be finalised. This could have resulted in players recovering from their injuries by the time of testing.

This study shows that there are statistically significant ($p=0.01$) reductions in WMS-R: delayed memory from pre-season to post-season in the group of players with repetitive vMTBI's during a single rugby season. This is the first evidence of possible neurocognitive deficits towards delayed memory in very mild traumatic brain injuries at secondary school level in rugby. The delayed memory in vMTBI may have the same negative effects on a participant's academic performance, as stated in previous research on MTBI (Ackermann, 2000), if the participant should take part in school examinations immediately after a vMTBI.

In 1999, Collins *et al.* studied 393 male college football players to assess the relationship between concussion history and learning difficulties and the association of these variables with neuropsychological performance. A significant interaction between learning disabilities and histories of multiple concussions and between learning disabilities and two of the tested neuropsychological measures (executive functioning and speed of information processing) were observed. The study concluded that both histories of multiple concussions and learning disabilities were associated with reduced cognitive performance (Collins *et al.*, 1999).

Individuals with mild traumatic brain injuries presenting at emergency services in hospitals, have shown statistically significant differences in measures of different aspects of cognitive functioning including attention, concentration, short-term memory, delayed memory and speed of information processing, compared with matched controls (Bohnen *et al.*, 1992).

Although neuropsychological testing is gaining increasing acceptance among sport medicine practitioners, several practical issues have limited its widespread implementation at college and secondary school level. Evaluation of an entire team is time- and labour intensive and many schools are reluctant to embrace these tests because of limited financial resources.

It is recommended that neuropsychological testing should remain one of the cornerstones of MTBI evaluation in complex concussion and must be managed in a multidisciplinary manner for return to play decision-making and for the neurocognitive health of individuals (Aubry *et al.*, 2002; Bleiberg *et al.*, 2004).

In conclusion, this study shows that there is statistically significant reduction in cognitive functioning, as shown in the results of the WMS-R: Delayed memory and the SAC, after repetitive vMTBI and MTBI in secondary school rugby players.

4.5 RECOMMENDATIONS

The main limitations of this study are the small sample size and the period (2-4 weeks) that elapsed after the last rugby game of the season before post-seasonal testing was conducted, giving enough time for recovery of vMTBI and MTBI. External factors such as school examinations and sickness of participants were the reasons for the 2-4 week delay before post-season testing could be finalised.

It is recommended that a larger, on going prospective study, with pre-season baseline testing and possible computerised neuropsychological test batteries be conducted in future in secondary school rugby players to confirm findings of this study and possible other cognitive impairments due to repetitive vMTBI's and MTBI's.

Further investigations into this study's findings may lead to a safer return to play in schoolboy rugby in the future.

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CHAPTER 5

The academic consequences of very mild traumatic brain injuries and mild traumatic brain injuries in a secondary school rugby team – A comparison between very mild traumatic brain injuries, mild traumatic brain injuries and a sedentary control group

Contents

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This article will be submitted to the *South African Journal for Research in Sport, Physical Education and Recreation*

THE ACADEMIC CONSEQUENCES OF VERY MILD TRAUMATIC BRAIN INJURIES AND MILD TRAUMATIC BRAIN INJURIES IN A SECONDARY SCHOOL RUGBY TEAM –

A comparison between very mild traumatic brain injuries, mild traumatic brain injuries and a sedentary control group.

J.A. LAUBSCHER, H.P. DIJKSTRA, G.L. STRYDOM & E.PETERS

Abstract

Objective ***- Information on the consequences of MTBI on secondary school rugby players has been documented, but studies on the academic consequences of repetitive sub-concussive injuries or so-called very mild traumatic brain injuries (vMTBI) are lacking. The aim of this study was to compare the last three years academic performances of a team of secondary school rugby players suffering with very mild traumatic brain injuries, mild traumatic brain injuries and a sedentary control group. The neuropsychological test results were compared with the academic performances of the subjects.***

Methods ***– A cohort of 35 secondary school male rugby players (that was divided into a sub-concussive (vMTBI) group (group 1)(n=26) and a concussive (MTBI) group (group 2) (n=9) at the end of a secondary school rugby season) and ten (n=10) participants that is not involved in contact sports as a control group (group 3), were used in this study. The control group was schoolboys that did not participate in any contact sport. The academic results of the different subjects (Afrikaans, English, Mathematics and Science) were obtained from the secondary school. Pre-season baseline and post-season pen and paper neuropsychological tests (SAC, Colour Trial Test (CTT) 1 and 2, Digit Symbol Modalities Test (DSMT) and Wechsler Memory Scale-Revised (WMS-R) Test for verbal, visual, general, delayed memory and attention/concentration) were then compared with the academic performance of the subjects.***

Note: In this study, the term mild traumatic brain injuries (MTBI) refers to the term concussion and the term very mild traumatic brain injuries (vMTBI) refers to the term sub-concussive injuries and will be used interchangeably throughout this study. Group 1 =vMTBI, group 2 = MTBI & group 3 = control group. The results of the final examination (year 1) of the year of the specific rugby season were used, as well as the results of the final examination of the previous year (year 2) and the final examination the year before that (year 3).

Results ***– Group 1 (vMTBI group) and group 2 (MTBI group) showed a statistically significant ($p \leq 0.05$) decrease in academic performance in the subject Afrikaans when compared between year 1 and year 2, with a p-value of $p=0.017$ (group 1) and $p=0.016$ (group 2) respectively. No statistical significance was found between the neuropsychological test results and the academic performances of the subjects.***

Conclusion ***– The findings in this study indicate a statistically significant decrease in academic performance $p=0.017$ (group 1) and $p=0.016$ (group 2) in the subject Afrikaans from the previous year final examination to the final examination during the year of the study. A multi-centred prospective study, ensuring a large enough sample size and more neuropsychological and academic performance data is necessary to evaluate more definite findings.***

Keywords: Academic performance; Concussion; Neuropsychological tests; Rugby; Sub-concussive injuries; Traumatic brain injuries.

5.1 INTRODUCTION

Rugby is one of the popular sports played in South African English and Afrikaans medium schools (Ackermann, 2000). The risk of sustaining a head injury is increased whenever a rugby player performs competitively, entailing physical contact with another player or object (Clark *et al.*, 1990; Gibbs, 1993; Wekesa *et al.*, 1996; Pettersen, 2002).

Note: In this study, the term mild traumatic brain injuries (MTBI) refers to the term concussion and the term very mild traumatic brain injuries (vMTBI) refers to the term sub-concussive injuries and will be used interchangeably throughout this study. Group 1 =vMTBI, group 2 = MTBI & group 3 = control group. The results of the final examination (year 1) of the year of the specific rugby season were used, as well as the results of the final examination of the previous year (year 2) and the final examination the year before that (year 3).

Mild traumatic brain injury (MTBI) or concussion as used interchangeably in the literature (Maroon *et al.,* 2000; Wills & Leathem, 2001) is important public health concerns due to the high incidence and frequently persisting symptomatology (Evans, 1992). The term concussion enables the use of an additional description within the spectrum of mild traumatic brain injuries, namely sub-concussive injuries that are explained in the literature as involving subtle changes in consciousness, difficult to detect with symptoms usually lasting seconds to minutes (De Villiers, 1987), therefore a very mild traumatic brain injury (vMTBI). A Sub-concussive injury or very mild traumatic brain injury may be defined as an apparent brain insult with insufficient force to cause hallmark symptoms of concussion (Jordan, 2000; Webbe & Bath, 2003).

Mild traumatic brain injuries (MTBI) in children gained public health attention as an under investigated disorder with potentially serious cognitive and behavioural outcomes (Satz *et al., 1997;* Silver & McAllister, 1997). There is still a lack of consensus regarding the outcome of mild traumatic brain injuries and very mild traumatic brain injuries (vMTBI) in children (Satz *et al.*, 1997).

A study that examined neuropsychological function in secondary school children following MTBI, found a significant relationship between incidence of MTBI and attention deficit, language and reading disorders (Segalowitz & Lawson, 1995).

Another study compared 29 adolescents who sustained MTBI with a control group of healthy adolescents with an extensively neuropsychological test battery (Basset & Slater, 1990). Results indicated impairments in the MTBI group on measures of learning, abstraction and reasoning. They concluded that adolescents who are recovering from even a mild traumatic brain injury might be expected to experience difficulty on returning to school.

Some of the difficulties are related to the task conditions they are required to work under, as the school classroom is regarded as presenting the scholar with a vast amount of complex material in an environment full of distractions (Basset & Slater, 1990).

It has been argued that one of the most disturbing features of MTBI and possibly vMTBI is the fact that its effects may be cumulative (De Villiers, 1987). A previous study compared young adults who sustained a second or third MTBI with a control group consisting of persons with a first MTBI (Gronwall, 1989). They found that information processing ability was slowed in the persons with a second or third MTBI, when compared to a single MTBI. Furthermore, those who sustained multiple MTBI's took longer to return to normal levels of functioning. It appears that the consequences following a MTBI may be cumulative even after a person has recovered clinically and in fact, that the course of recovery is prolonged after each successive injury.

A study by Beilinsohn (2001) reported that the recognition of the presence of deficits in working memory, verbal new learning and speed of hand motor dexterity is vital in order to cope with ensuing reductions in scholastic and occupational abilities. They argue that these comprised higher cognitive functions, which have particular consequences for students who rely heavily on these exact skills to achieve optimal academic performance. Furthermore, the study emphasizes that the risks for matriculation school rugby players are particularly high, as many will be attempting to obtain entrance into competitive and demanding tertiary programmes. This is also true for borderline achievers, who may be in danger of failing pre-injury and for whom any further slight reduction in functioning may have a potentially disastrous outcome. The study recommended that any player who has sustained a MTBI should be advised to delay undertaking of any task that would require optimal academic performance for at least three months post-injury (Beilinsohn, 2001).

Generally, if attempts are made to undertake tasks in the face of unrecognised MTBI effects, this can result in unexpected failure and set up a cycle of negative psychological consequences such as depression and self-doubt (Shuttleworth-Jordan *et al.*, 1993). It is, therefore, safe to conclude that there is a risk of increasingly negative consequences from subsequent head injuries (Levin *et al.*, 1987).

The aim of this study is to investigate the academic consequences of very mild traumatic brain injuries (vMTBI) and mild traumatic brain injuries (MTBI) in secondary school rugby players, when compared to each other and a sedentary control group.

5.2 MATERIALS AND METHODS

5.2.1. Selection of research group

The research group in this study was rugby players playing for the first and second teams at a secondary school, which were two groups (group 1 = vMTBI & group 2 = MTBI), with an average age of 17.4 years. Thirty-five (35) rugby players participated (players from the school's first (n=15) and second (n=15) teams and reserve players (n=5) playing for the third team). Ten (n=10) participants that was not involved in contact sports were used as a control group (group 3).

The control group was selected randomly from the same school where the rugby players were selected, with the same age, gender and education level and consisted of schoolboys that did not play any contact sport. The control group was selected from the grade 11 (aged 17) and grade 12 (aged 18) groups of the school by eliminating all the rugby playing learners and using the chance figures according to Steyn *et al.* (1995) to randomly select the control group.

Persons with diagnosed learning disabilities, previous concussions, epilepsy and drug abuse were not considered for the control group of this study. After the study was discussed with the participants and in letter format with the parents, all the participants, parents or guardians gave informed consent. The subject's personal information that was gathered by this study was held strictly confidential. The Ethics Committee of the North-West University approved the study.

5.2.2. Measuring instruments

5.2.2.1. Academic report

The academic results of all three groups in this study were obtained from the secondary school. The results of the final examination (year 1) of the year of the specific rugby season were used, as well as the results of the final examination of the previous year (year 2) and the final examination the year before that (year 3). The subjects Afrikaans, English, Mathematics and Science were followed by most of the participants in this study and this is the reason why only these four subjects were analysed.

5.2.2.2 Neuropsychological test and academic performance

Baseline and post-seasonal neuropsychological assessment

The pre-season and post-season neuropsychological tests were done on group 1, group 2 and the control group (group 3) for the different pen and paper neuropsychological test (CTT, SDMT, WMS-R and the SAC) and then compared with academic results (all three years) of the subjects. (See **Appendix A** for Neuropsychological tests).

After each match played throughout the season the research group also completed a SAC test. The rugby season was approximately five months long. Individual players vary with respect to their levels of performance on tests of memory, attention/concentration, mental processing speed and motor speed. The following neuropsychological tests were used in this study.

5.2.2.2.1 The Symbol Digit Modalities Test (SDMT) (Smith, 1982)

The SDMT consists of eight rows containing in all 110 small blank squares, each paired with a randomly assigned symbol that will be compared with a number from one to nine, to test the subject's concentration and visual memory ability. Above these rows is a printed key that pairs each number with a different non-sense symbol. Following a practice trial on the first ten squares, the task is to fill in the blank spaces with the number that is paired to the symbol above the blank space as quickly as possible for 90 seconds. The score is the number of squares filled in correctly (Smith, 1982). See **Appendix A** for the Digit Symbol Modalities Test.

5.2.2.2.2 The Colour Trial Test (CTT) (Maj *et al.*, 1993)

In Colour Trial Test-1 subjects are given a page with scattered circles numbered from one to 25, with even-numbered circles coloured yellow (Y) and the odd-numbered ones coloured pink (P). The task requires the subject to draw a line following the number sequence. Colour Trial Test-2 also presents the subject with a page containing 25 circles, but on this sheet each colour set is numbered to 13 for the yellow odd numbers and to 12 for the pink even ones.

The task is to follow the number series with a pencil by alternating between the two colours as well (1Y-1P-2Y etc.) The CTT is used to test the subject's concentration and visual memory ability. See **Appendix A** for the Colour Trial Test-1 and Test-2.

5.2.2.2.3 Wechsler Memory Scale–Revised (WMS-R) (Wechsler, 1987)

The Wechsler Memory Scale-Revised comprises a series of brief subtests, each measuring a different facet of memory (Wechsler, 1987). See **Appendix A** for the Wechsler Memory Scale–Revised (WMS-R) test. The following subtests with their different measuring facets were used:

- *Information and Orientation Questions*

  This subtest contains simple questions covering biographical data, orientation and common information from long-term memory. Questions 1 to 7 requested the examinee's name and other relative information. Questions 8 to 14 concerned the individual's orientation in time (date, time of day) and place (locality, place of testing). The last two questions concerned the individual's hand preference and whether he or she has any impairments of hearing or vision that could influence performance on some of the WMS-R subtests (Wechsler, 1987).

- *Mental control*

  The three items of this subtest are, counting backward from 20 to 1 recording the time in seconds. The time limit is 30 seconds. Name the letters of the alphabet and record the time in seconds. The time limit is 30 seconds. Counting in 3's, record the time in seconds. The time limit is 45 seconds (Wechsler, 1987). This subtest will test the subject's memory and concentration levels.

- *Figural memory*

  This subtest measures memory for figural stimuli. Figural memory involves showing the examinee a set of abstract designs. Then, after each set of designs is removed, the examinee is asked to identify the designs within a larger set of designs (Wechsler, 1987).

- *Logical memory I (Immediate recall)*

  This subtest consists of two brief stories that are read to the examinee. After each story, the examinee retells the story from memory (Wechsler, 1987).

- *Visual paired associates I (Immediate recall)*

  This subtest requires the examinee to learn the colour associated with each of six abstract line drawings. In order to minimise the role of verbal mediation in memorising and responding to the figure-colour pairs, the colour names are not used either in presenting the items or in responding to them. The pairs are presented until the examinee answers all six items correctly, however, only the first three presentations are scored and no more than six presentations are given. Using six presentations insures that the examinees learn the material to the criterion of one perfect repetition (Wechsler, 1987).

- *Verbal paired associates I (Immediate recall)*

  In this subtest a group of eight word pairs are read to the examinee, then the first word of each pair is read and the examinee is asked to supply the second word from memory. Only the first three presentations are scored, although six presentations are given (Wechsler, 1987).

- *Visual reproduction I (Immediate recall)*

  The examinee looks at a geometric design and is then asked to draw it from memory (Wechsler, 1987).

- *Digit span*

  The two parts of the Digit Span subtest, 'Digits Forward' and 'Digits Backward', are administered separately. On 'Digits Forward', number sequences of increasing length are read to the examinee. After each sequence the examinee is asked to repeat them from memory. On 'Digits Backward', similar number sequences are read to the examinee and after each sequence the examinee is asked to repeat them backwards. Administer 'Digits Backward' even if the examinee does poorly on 'Digits Forward' (Wechsler, 1987).

- *Visual Memory Span*

  The two parts of the Visual Memory Span subtest, Tapping Forward and Tapping Backward are administered separately. In Tapping Forward the examinee watches the examiner touch the red squares on Card 1 in sequences of increasing length, and after each sequence is asked to repeat the performance from memory. In Tapping Backward the examinee watches the examiner touch the green squares on Card 2 in sequences of increasing length, and is asked to repeat the performance in reverse. Administer Tapping Backward even if the examinee does poorly on Tapping Forward (Wechsler, 1987).

- *Logical Memory II (Delayed recall)*

  This subtest was administered at least 30 minutes after completion of Logical Memory I. If necessary, pause after Visual Memory Span to ensure that at least 30 minutes have elapsed (Wechsler, 1987).

- *Visual Paired Associates II (Delayed recall)*

  This subtest was administered at least 30 minutes after completion of Visual Paired Associates I (Wechsler, 1987).

- *Verbal Paired Associates II (Delayed recall)*

  This subtest was administered at least 30 minutes after completion of Verbal Paired Associates I (Wechsler, 1987).

- *Visual Reproduction II (Delayed recall)*

  This subtest was administered at least 30 minutes after completion of Visual Reproduction I (Wechsler, 1987).

5.2.2.2.4 Standardised Assessment of Concussion (SAC) (McCrea *et al.*, 1998)

The Standardised Assessment of Concussion (SAC) is a brief screening instrument designed for the neurocognitive assessment of concussion. This assessment can be used by a non-neuropsychologist that has no prior expertise in psychometric testing to test subjects. The SAC requires approximately five minutes for assessment of four domains of cognition, including orientation, immediate memory, concentration and delayed recall, summing to a total composite score of 30 points. Three equivalent alternate forms of the test will be used in this study to minimise practice effects from repeated administration (McCrea *et al.*, 1998). See **Appendix A** for the Standardised Assessment of Concussion (SAC) test.

Neuropsychological testing represents the most sensitive and practical method available for delineating cognitive and neurobehavioural events associated with MTBI, and involves the application of neuropsychological test instruments that are sensitive even to subtle changes in attention, concentration, memory, information processing and motor speed or co-ordination (Lezak, 1995), which could be detected in vMTBI. All these neuropsychological tests (CTT, SDMT, WMS-R and the SAC) used in this study have been used extensively in other studies (McCrea *et al.*, 1998; Collins *et al.,* 1999; Lovell & Collins, 1999) and comply with scientific criteria regarding to validity and reliability.

5.2.3. Statistical analysis:

The programme STATISTICA (version 7.0, Stat soft, Tulsa, OK) was used to analyse the data and divide it into the following statistical analysis.

Descriptive statistics were used on each group to obtain the means and standard deviation of their academic performance as shown in Table 5.1. Two-way repeated measures ANOVA's were used to compare the academic results of the subjects Afrikaans, English, Science and Mathematics. The p-value for significance was set at ≤ 0.05. One way Post-hoc Tuckey HSD analysis was applied to examine significant differences ($p \leq 0.05$) between pairs of means in each group on results of all the academic results. The relationships between the neuropsychological test and academic variables were analysed using Pearson's product moment correlation and the statistical significance was set at $p \leq 0.05$.

5.3 RESULTS AND DISCUSSION

Table 5.1 reports the descriptive information on the academic results in the subjects Afrikaans, English, Mathematics and Science in all three groups.

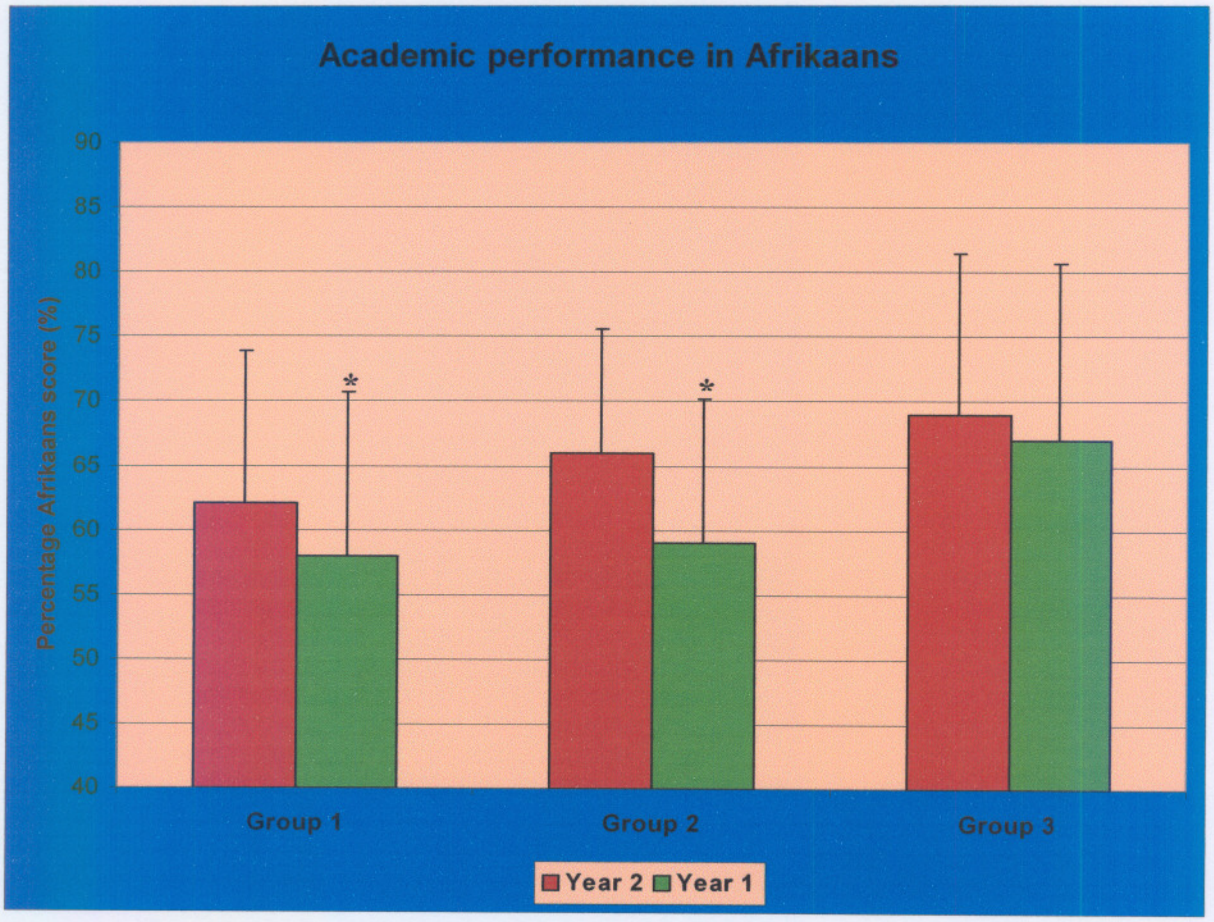
Table 5.1: Descriptive information on the academic performance

Variables	Group	N	Mean	SD
Year 1: (See note)				
Afrikaans	1	26	58.6	12.7
	2	9	59.2	11.2
	3	10	67.2	13.7
English	1	26	54.0	14.1
	2	9	58.0	13.8
	3	10	63.4	12.7
Mathematics	1	23	50.0	12.9
	2	9	54.3	13.2
	3	10	58.3	17.4
Science	1	10	57	9.9
	2	7	58.1	14.7
	3	7	69.0	11.9

Variables	Group	N	Mean	SD
Year 2: (See note)				
Afrikaans	1	26	61.5	11.9
	2	9	65.4	9.6
	3	10	69.5	12.5
English	1	26	53.8	15.1
	2	9	57.0	15.2
	3	10	60.8	13.4
Mathematics	1	23	49.5	16.4
	2	9	58.3	16.9
	3	10	63.0	18.4
Science	1	13	58.9	11.2
	2	8	55.8	19.1
	3	7	72.9	8.4
Year 3: (See note)				
Afrikaans	1	26	58.3	13.6
	2	9	60.8	11.5
	3	10	67.1	10.7
English	1	26	56.6	13.5
	2	9	63.3	15.1
	3	10	60.9	14.4
Mathematics	1	23	53.4	20.9
	2	9	55.8	22.1
	3	10	62.0	21.5
Science	1	15	56.9	16.9
	2	8	64.4	16.0
	3	9	60.3	21.5

Figure 5.1 shows the academic performance in Afrikaans for year 1 compared with year 2 in all three groups.

Figure 5.1: Academic performance in the subject Afrikaans in year 1 compared with year 2



Year 1 represents the rugby season's final examination ("post-season") and year 2 the previous year's final examination ("pre-season").

*** = p ≤ 0.05 (Statistically Significant p=value)**

No statistically significant ($p \leq 0.05$) results were found in the 3 groups English, Mathematics and Science when compared, but in the subject Afrikaans a statistically significant decrease in academic performance was found (Figure 5.1).

All three groups, performances decreased from year 2 (the previous year's final examination) to year 1 (rugby season's final examination). With regard to this, group 1 (vMTBI group) and group 2 (MTBI group) showed a statistically significant decrease in academic performance in the subject Afrikaans with a p-value of $p=0.017$ (group 1) and $p=0.016$ (group 2) respectively (shown by the * in Figure 5.1). Year 3 was not further investigated because of no statistically significant findings.

The above findings may support previous literature on the psychosocial and academic hardship as the presence of subtle deficits following mild and very mild traumatic brain injuries go undetected, especially in a school context (Boll, 1983; Boll, 1985). In this regard, a child who may appear attentive may in fact be struggling to concentrate and may subsequently fail to perform and therefore risk the disapproval of peers and teachers (Boll, 1983; Boll, 1985). Furthermore, children with mild and very mild traumatic brain injuries experience personality changes, headaches, irritability, school learning difficulties and memory and attention problems (Boll, 1983; Boll, 1985).

The cognitive consequences following MTBI are similarly broad and may include memory impairment and difficulties in attention and concentration, deficits in language use and visual perception. Frontal lobe functions such as executive skills of problem solving, abstract reasoning, insight, judgement, planning, information processing and organisation can also be associated with MTBI (Collins *et al.,* 1999; Borek *et al.,* 2001; Aubrey *et al.,* 2002).

Some of the common behavioural deficits after MTBI include a decreased ability to initiate responses, verbal and physical aggression, agitation, learning difficulties, shallow self-awareness, altered sexual functioning, impulsivity, social disinhibition, mood disorders, personality changes, altered emotional control, depression and anxiety (Borek *et al.,* 2001).

In one study, referred patients to a neuropsychiatric brain injury unit showed evidence of neuropsychiatric symptoms in right-sided brain injury, while impairment of intellectual ability (cognitive impairment) was associated with injury to the left side of the brain (Borek *et al.,* 2001). The long-term effects on social function may include increased suicide risk, divorce, chronic unemployment, economic strain and substance abuse (Collins *et al.,* 1999; Aubrey *et al.,* 2002).

No statistical significant p-values were found when the neuropsychological tests and the academic performances were correlated.

5.4 CONCLUSION

The growing body of evidence indicating the risk of permanent residual cognitive impairment as a result of cumulative mild and very mild traumatic brain injuries has raised public health attention, due to the implication of such findings for contact sport. This is because the nature of contact sport predisposes players to the risk of repeated injury, and more specifically, to multiple MTBI's or vMTBI's (Beilinsohn, 2001).

The high risk of effects following a mild traumatic brain injury is particularly relevant to schoolboys who are aiming for competitive scholarships, or for borderline achievers who are already in danger of failing pre-injury (Shuttleworth-Jordan *et al.,* 1993). In such individuals, a permanently reduced level of functioning, however slight, might be a factor that tips the balance with significantly disruptive effects (Shuttleworth-Jordan *et al.,* 1993).

Sports activities are designed to produce healthy bodies and minds and when the result of such activity is the impairment of health, the question of ongoing or continued participation in the activity may be relevant (Bruce *et al.*, 1982). Any such injuries may require follow-up with further investigation. In the overall framework of the child's life, organised sport activities are safe and should be encouraged.

5.5 RECOMMENDATIONS

The main limitations of this study are the small sample size, the short period of analysing the participants (only one rugby season) and the external factors that could have had an effect on the academic performances, namely alcohol use, possible unreported head injuries outside the rugby scenario (motor vehicle accident or bumping head against the ground from a fall) and previous learning difficulties at an earlier stage, specifically with the rugby players who were not randomly chosen, but selected by the team for which they were playing. It is recommended that a larger, on going prospective study from the start of playing secondary school rugby (also with pre-season baseline and post-season testing and possible computerised neuropsychological test batteries) should be conducted on secondary school rugby players to confirm findings of this study and possible other cognitive impairments due to repetitive vMTBI's in rugby.

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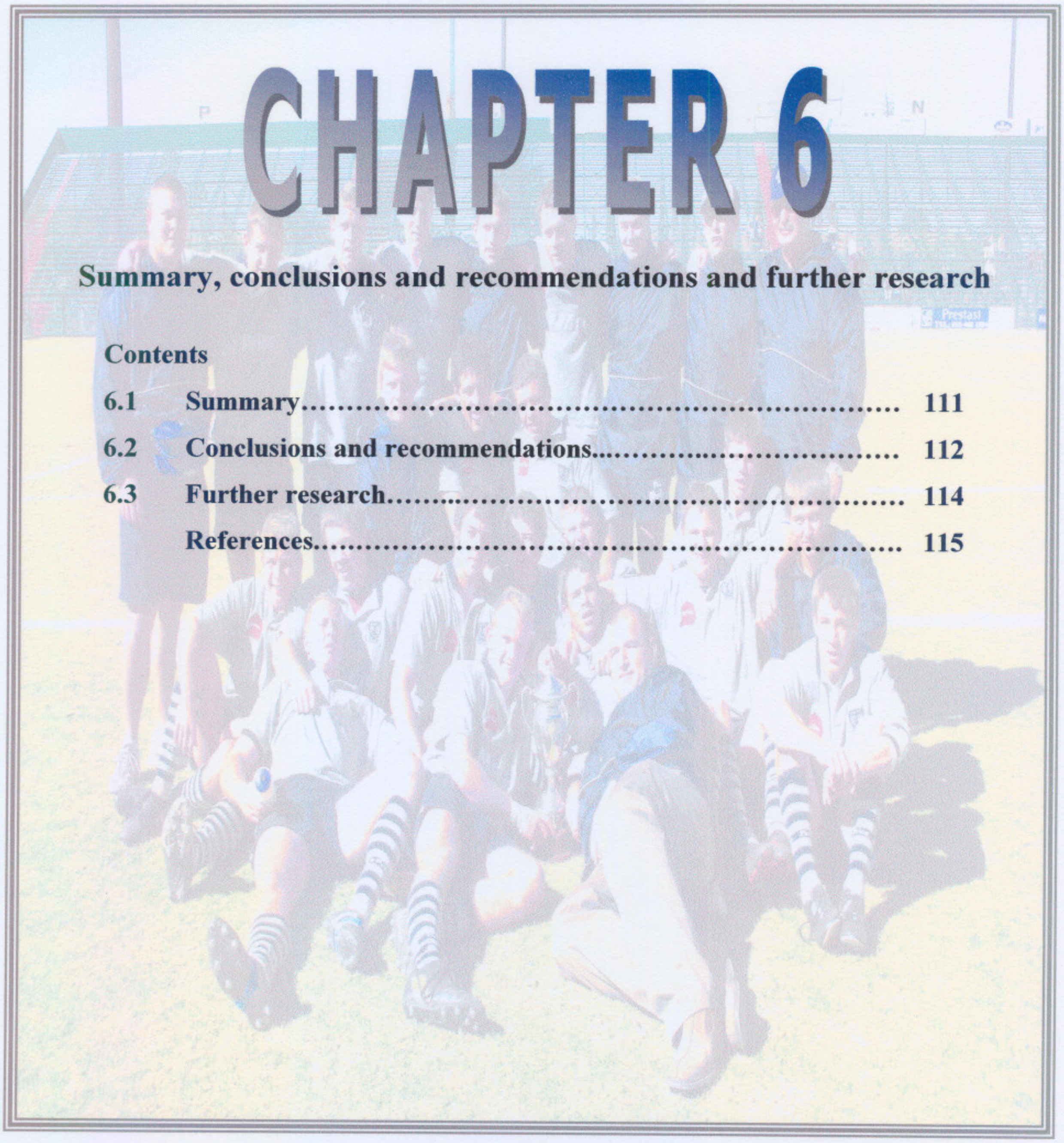

CHAPTER 6

Summary, conclusions and recommendations and further research

Contents

6.1 SUMMARY

Mild traumatic brain injuries (MTBI) or concussion as used interchangeably in the literature (Maroon *et al.,* 2000; Wills & Leathem, 2001) are one of the most important public health concerns, due to its high incidence and its frequently persisting symptomatology (Evans, 1992). The high incidence of sport-related head injuries in South Africa is alarming, although the prevalence thereof is unknown and difficult to assess as the seemingly trivial injuries frequently remain unreported (Roux *et al.*, 1987). Very mild traumatic brain injuries (vMTBI) or so-called sub-concussive injuries are subtle and often overlooked. It is also likely that the incidence and consequences of MTBI and vMTBI in secondary school rugby may be under-reported (Roux *et al.*, 1987). The potential long-term cumulative effect poses a direct threat to the neurocognitive well being of the young rugby player with MTBI and vMTBI.

This study of a secondary school rugby team has shown 726 very mild traumatic brain injuries and 18 mild traumatic brain injuries in one rugby season. This relates to 1951 vMTBI per 1000 player hours and 48 MTBI per 1000 player hours.

Neuropsychological tests are now commonly used to provide an objective measure of cognitive function and recovery after a MTBI or vMTBI. Given that individuals vary considerably in their performance on many neuropsychological tests, interpretation of results after MTBI and vMTBI is facilitated by knowledge of baseline scores for each player.

Subtle reductions in delayed memory from pre-season to post-season in a group of players with repetitive vMTBI's during a single rugby season were found. This was the first evidence of possible neurocognitive deficits towards delayed memory in vMTBI at secondary school level.

In the school-aged athlete, the reporting of all injuries should be encouraged. Any injury, however transient, involving the central nervous system should be reported and the child should be examined by a specialised physician.

Arguably, the most important aspect of prevention is education of team physicians and others involved in participants' care. On-field recognition of concussive injuries remains a priority, as well as the application of appropriate validated guidelines in returning safely to sport.

6.2 CONCLUSIONS AND RECOMMENDATIONS

In this study the following were found:

- The incidence of repeated very mild traumatic brain injuries (726 injuries) and mild traumatic brain injuries (18 injuries) throughout one secondary school rugby season was high. The incidence relates to 1951 very mild traumatic brain injuries per 1000 player hours and 48 mild traumatic brain injuries per 1000 player hours.

  The incidence of very mild traumatic brain injuries in the different playing positions was 24% in the eighth man position, 16% in the fullback, 14% in the locks, 13% in the hooker and 11% in the scrumhalf position. In comparison, the incidence of mild traumatic brain injuries in the flankers was 39%, in the wings 17% and in the centers 17%. A clear indication that the forwards sustain more very mild traumatic brain injuries than the back line was evident from the data.

  The very mild traumatic brain injuries in the different phases of the game had an incidence of 40% in the loose-scrum phase, 32% in the tackle phase and 14% in the open play phase. The mild traumatic brain injuries had an incidence of 61% in the tackle phase and an incidence of 39% in the loose-scrum phase. The highest incidence of very mild traumatic brain injuries and mild traumatic brain injuries was in the loose-scrum and the tackle phase as shown in the data.

Hypothesis 1 that states that the incidences of mild (MTBI) and very mild traumatic brain injuries (vMTBI) are high amongst secondary school rugby players is accepted.

- A statistically significant difference ($p=0.01$) was observed in the WMS-R: Delayed Memory test between the very mild traumatic brain injuries group's baseline score and its post-season score (baseline ability level was high average and post-season ability level average). The statistical significance implicated that very mild traumatic brain injuries had a negative impact on the very mild traumatic brain injuries group's delayed memory. Subtle, but statistically significant reductions in the SAC test (total score) throughout a single rugby season in the group of players with repetitive vMTBI when compared with the baseline test were found. The same results were obtained in the SAC test (total score) throughout a single rugby season in the group of players with MTBI when compared with the baseline test. Hypothesis 2 that states that mild (MTBI) and very mild traumatic brain injuries (vMTBI) in rugby have significant consequences on memory and concentration in a secondary school rugby team is accepted because of the statistically significant reduction ($p=0.01$) of delayed memory in the very mild traumatic brain injuries group and the baseline test and SAC totals (Table 4.3) of the very mild traumatic brain injuries and mild traumatic brain injuries group.

- Group 1 (very mild traumatic brain injuries group) and group 2 (mild traumatic brain injuries group) showed a statistically significant decrease in academic performance in the subject Afrikaans with a p-value of $p=0.017$ (group 1) and $p=0.016$ (group 2) respectively between year 1 and year 2. This implicates that mild and very mild traumatic brain injuries may have some effect on the academic performance in the subject Afrikaans of rugby players in their final school examinations. Hypothesis 3 that states that the repeated mild (MTBI) and very mild traumatic brain injuries (vMTBI) in rugby has a significant negative effect on the secondary school rugby player's academic performance is partially accepted because of the statistically significant reduction in performance in both groups ($p=0.017$) and ($p=0.016$) for the subject Afrikaans.

6.3 FURTHER RESEACH

- The main limitations of this study were the small sample size and a period (2-4 weeks) that elapsed after the last rugby game of the season before post-seasonal testing could be conducted, possibly giving enough time for recovery of very mild traumatic brain injuries and mild traumatic brain injuries, which could have had an effect on results. External factors such as examinations and sickness of participants were the reasons for the 2-4 week delay before post-season testing could be finalised.

- It is recommended that a larger, on going prospective study from the start of playing secondary school rugby (also with pre-season baseline and post-seasonal testing and possible computerised neuropsychological test batteries) should be conducted on secondary school rugby players to confirm findings of this study and possible other cognitive impairments due to repetitive vMTBI's in rugby.

- It is also recommended that such a study (incidence and consequences of repetitive vMTBI) should be conducted on college/university level rugby players.

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APPENDIX A

Appendix A has Afrikaans and English sections. The reason for this is that the questionnaires that were given to the participants were in Afrikaans, so that they could process the information in their home language. The neuropsychological tests were done in English in their original format, so that the standards could be as set.

Content

Questionnaires

- **Die insedensie van geringe en baie geringe traumatiese brein beserings in sekondêre skole rugby – Demografiese inligting**
- **Die insedensie van geringe en baie geringe traumatiese brein beserings in sekondêre skole rugby – Na-wedstrydse Evaluering**

Consent

- **Ingeligte toestemmings brief**

Neuropsychological tests

- **The Standardised Assessment of Concussion (SAC)**
- **Symbol Digit Modalities Test (SDMT)**
- **Colour Trial Test (CTT)**
- **Wechsler Memory Scale-Revised (WMS-R)**

DIE INSIDENSIE VAN GERINGE EN BAIE GERINGE TRAUMATIESE BREIN BESERINGS IN SEKONDêRE SKOLE RUGBY

Demografiese Inligting:

Naam & Van: ______________________

Ouderdom: ______________________

Span: ______________________

Spelersposisie: ______________________

Antwoord die volgende vrae deur die toepaslike antwoord te merk:

- Het jy al harsingskudding in die huidige seisoen gehad? Ja / Nee
- Hoeveel keer in die huidige seisoen? 1 2 3 ____
- Het jy jou bewussyn verloor? Ja / Nee
- Het 'n mediese Dokter jou behandel vir die harsingskudding? Ja / Nee
  Naam van Dokter: ______________________
- Is jy gehospitaliseer vir die harsingskudding? Ja / Nee
- Gebruik jy 'n kopskerm tydens rugbywedstryde? Ja / Nee
- Gebruik jy 'n mondskerm tydens rugbywedstryde? Ja / Nee
- Hoe lank speel jy al rugby? ______________

- Het jy al ooit 'n nekbesering in rugby opgedoen? Ja / Nee

  Hoeveel keer: ____________________ Watter jaar: ____________

  - Geskiedenis van vorige harsingskudding:

Jaar	Aantal in jaar	Bewussyn verloor	Geheueverlies > 5 min of < 5 min	Behandeling ontvang en Dokters se naam

- Het jy 'n familie geskiedenis van epilepsie? (ouers/broers/susters) Ja / Nee

  Indien **Ja** spesifiseer ____

- Het jy ooit self-epilepsie gehad of behandeling daarvoor gekry? Ja / Nee

  Indien **Ja** spesifiseer ____

  ____

- Het jy koorstuipe as kind gehad? Ja / Nee

- Gebruik jy enige medikasie of aanvullings? Ook tydens die seisoen. (bv. kreatien, vitamiene)

  ____

  ____

- Het jy tans of voorheen behandeling ontvang vir depressie of enige ander sielkundige- of leerprobleem? Ja / Nee

  Indien **Ja** spesifiseer ____

  ____

- Hoe ervaar jy die volgende simptome op die huidige oomblik?

Simptome	Frekwensie	Intensiteit	Duur
• Hoofpyn	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Geirriteerd	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Voel depressief	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Geheue probleme	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Konsentrasie probleme	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Neem langer om te dink	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Angstig	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Frekwensie (hoeveel keer) is 1= nooit, 2= selde, 3= gewoonlik, 4= meeste van die tyd, 5= die heeltyd.

Intensiteit (hoe erg) is 1= nooit, 2= effens, 3= matig, 4= baie erg, 5= onuithoubaar.

Duur (hoe lank) is 1= nooit, 2= kort, 3= redelik, 4= lank, 5= konstant (heel tyd).

DIE INSIDENSIE VAN GERINGE EN BAIE GERINGE TRAUMATIESE BREIN BESERINGS IN SEKONDêRE SKOLE RUGBY

(Na-wedstrydse Evaluering)

Naam & Van: ______________________________

Span: ______________________________

Spelersposisie: ______________________________

Omkring die toepaslike antwoord by die volgende vrae:

1 Het jy met 'n kopskerm in vandag se wedstryd gespeel?

Ja / Nee

2 Het jy met 'n mondskerm in vandag se wedstryd gespeel?

Ja / Nee

3 Het jy enige stamp/stampe (hetsy baie lig of hard) teen die kop gekry tydens vandag se wedstryd waarvan jy bewus is?

Ja / Nee

4 In watter situasie/situasies in die wedstryd het jy die stamp teen die kop gekry?

Situasie:	**Aantal stampe in helfte:**	
	1ste	2de
Skrum		
Los-skrum		
Lynstaan		
Duikslag		
Dryf		
Ander: __________		

5 Het jy enige van die volgende simptome ervaar nadat jy die stamp teen die kop gekry het en hoe intens / erg het jy dit ervaar?

Simptome:	Ja / Nee:	Intensiteit:
• Hoofpyn	Ja / Nee	1 2 3 4 5
• Duiseligheid	Ja / Nee	1 2 3 4 5
• Van balans af	Ja / Nee	1 2 3 4 5
• Probleem om te fokus (visie)	Ja / Nee	1 2 3 4 5
• Naar	Ja / Nee	1 2 3 4 5
• Gedisoriënteerd (deurmekaar)	Ja / Nee	1 2 3 4 5
• Nek pyn	Ja / Nee	1 2 3 4 5

Hoe intens ervaar jy die simptoom op skaal van 1-5 waar 1=amper nie, 2= baie ligtelik, 3= erg, 4= baie erg, 5= onuithoubaar is.

6 Het jy enige behandeling op die veld, deur noodhulp, tydens die wedstryd vir die stamp teen die kop gekry?

Ja / Nee

7 Het die stamp wat jy teen die kop gekry het, veroorsaak dat jy die veld / wedstryd moes verlaat?

Ja / Nee

(Biokinetikus of Dokter kopstamp telling)

•	Hoeveel stampe waargeneem:
•	1ste / 2de Helfte:
•	Spelsituasie:
•	Behandeling gegee vir kop stamp:
•	Simptome waargeneem:
Dokter / Biokinetikus:	**Datum:**

DIE INSIDENSIE VAN GERINGE EN BAIE GERINGE TRAUMATIESE BREIN BESERINGS IN SEKONDêRE SKOLE RUGBY

Demografiese Inligting: (KONTROLE GROEP)

Naam & Van: ______________________

Ouderdom: ______________________

Geboorte datum: ______________________

Tel. Nr.: ______________________

Antwoord die volgende vrae deur die toepaslike antwoord te merk:

- Het jy ooit van tevore harsingskudde gehad? Ja / Nee
  Spesifiseer indien Ja:
  Jaar: ______________________
  Hoeveel: ______________________
  Hoe: ______________________

- Het 'n mediese Dokter jou behandel vir die harsingskudding? Ja / Nee
  Naam van Dokter: ______________________

- Is jy gehospitaliseer vir die harsingskudding? Ja / Nee

- Het jy 'n familie geskiedenis van epilepsie? (ouers/broers/susters) Ja / Nee
  Indien **Ja** spesifiseer: ______________________

- Het jy ooit self-epilepsie gehad of behandeling daarvoor gekry? Ja / Nee
  Indien **Ja** spesifiseer: ______________________

- Het jy koorstuipe as kind gehad? Ja / Nee

- Gebruik jy enige medikasie / alkohol / dwelms op die huidige oomblik?

____

____

- Het jy tans of voorheen behandeling ontvang vir depressie of enige ander sielkundige- of leerprobleem? Ja / Nee

  Indien **Ja** spesifiseer: ______________________________

- Noem al die sportsoorte waaraan jy die afgelope 5-jaar deelgeneem het en enige ernstige beserings wat jy opgedoen het daarin (beserings waarvoor jy mediese behandeling ontvang het)?

____

____

____

____

____

- Hoe ervaar jy die volgende simptome op die huidige oomblik?

Simptome	Frekwensie	Intensiteit	Duur
• Hoofpyn	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Geirriteerd	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Voel depressief	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Geheue probleme	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Konsentrasie probleme	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Neem langer om te dink	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
• Angstig	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Frekwensie (hoeveel keer) is 1= nooit, 2= selde, 3= gewoonlik, 4= meeste van die tyd, 5= die heeltyd.

Intensiteit (hoe erg) is 1= nooit, 2= effens, 3= matig, 4= baie erg, 5= onuithoubaar.

Duur (hoe lank) is 1= nooit, 2= kort, 3= redelik, 4= lank, 5= konstant (heel tyd).

Ingeligte toestemmings brief:

U word uitgenooi om deel te neem aan die navorsingsprojek van Rines Laubscher tot die doel vir die verwerwing van sy Doktoraal (PhD):

Titel van projek:

THE NEUROPSYCHOLOGICAL AND ACADEMIC CONSEQUENCES OF REPEATED MILD AND VERY MILD TRAUMATIC BRAIN INJURIES IN RUGBY AT A SECONDARY SCHOOL

Ek, die ondergetekende ____ (volle name en van) het die gegewens in verband met die projek/proef genoem in Deel 1 en Deel 2 hiervan gelees en ook die mondelinge weergawe daarvan aangehoor en ek verklaar dat ek dit verstaan. Ek was die geleentheid gegun om tersaaklike aspekte van die projek/proef met die projekleier te bespreek en ek verklaar hiermee dat ek vrywillig aan die projek/proef deelneem. Ek gee hiermee my toestemming om as proefpersoon in bogenoemde projek op te tree. Ek vrywaar hiermee die Universiteit asook enige werknemer of student van die Universiteit, teen enige aanspreeklikheid wat teenoor my, in die loop van die projek/proef mag ontstaan. Ek onderneem verder om geen eise teen die Universiteit in te stel weens skade of persoonlikheidsnadeel wat ek weens die projek/proef mag ly nie, hetsy dit aan die nalatigheid van die Universiteit, sy werknemers of studente, of ander proefpersone mag ontstaan nie.

____

(Handtekening van proefpersoon)

Onderteken te ______________________________ op ______________________________

GETUIES

1. ______________________________
2. ______________________________

Onderteken te ______________________________ op ______________________________

Proefpersone onder die ouderdom van 21 jaar is die skriftelike toestemming van die ouer of wettige voog ook nodig:

Hiermee gee ek ____

(Volle name en van) ouer / wettige voog van die proefpersoon hierbo genoem toestemming dat hy/sy aan hierdie projek/proef mag deelneem en ek vrywaar hiermee die Universiteit asook enige werknemer of student van die Universiteit, teen enige aanspreeklikheid wat teenoor my in die loop van die projek/proef mag ontstaan.

Handtekening: ______________________________ Datum: ______________________________

Verwantskap: ______________________________

DEEL 1

Inligting tot die navorsingstudie:

1. **Skool (vakgroep)/Instituut:** Skool vir Biokinetika, Rekreasie en Sport Wetenskap.
2. **Titel van projek/proef:** The neuropsychological and academic consequences of repeated mild and very mild traumatic brain injuries in rugby at a secondary school
3. **Volle name, van en kwalifikasies van projekleier/navorser:** Prof. H.P. Dijkstra, M.B.Ch.B., B.Sc. Hons.
4. **Rang/pos van projekleier/navorser:** Lektor by Noord-Wes Universiteit, Potchefstroom Kampus.
5. **Naam van toesighoudende geneesheer (waar van toepassing):** Dr. Paul Dijkstra.
6. **Die doel van die projek:**
   - Om die insedensie van geringe (harsingskudde) en baie geringe (ligte kop stampe) traumatiese brein besering in rugby op sekondêre skole vlak te rapporteer.
   - Om die moontlike gevolge van geringe en baie geringe traumatiese brein besering in rugby spelers op sekondêre skole vlak vas te stel deur gebruik te maak van neuropsigologiese toetse.
   - Om vas te stel wat se effek geringe en baie geringe traumatiese brein beserings op rugby spelers op sekondêre skole vlak se akademiese werk het.
7. **Verduideliking van die aard van alle prosedures wat gevolg sal word, insluitende identifisering van nuwe prosedures:**

   Fase 1 van die studie is die voltooiing van die ingeligte toestemmings vorms en 'n vraelys waarin die demografiese inligting van die proefpersoon weergegee word asook relevante inligting ten opsigte van die studie. 'n Voor-seisoense toetsing deur middel van neuropsigologiese toetse word dan gedoen voordat enige wedstryde gespeel word.

   Fase 2 van die studie is wanneer die spelers met rugbywedstryde begin. Na afloop van elke wedstryd sal die spelers/proefpersone direk na die wedstryd 'n vraelys invul wat die insedensie van geringe en baie geringe traumatiese brein besering rapporteer, asook een of twee vinnige neuropsigologiese toetse om die effek van die wedstryd waar te neem.

Hierdie prosedure sal deur die verloop van die hele seisoen gevolg word. Aan die einde van die rugby seisoen sal elke speler weer 'n eind toetsing deur middel van neuropsigologiese toetse ondergaan. Die proefpersone se akademiese rekords sal dan deur gegaan word om vas te stel of daar enige effek is wat moontlik deur geringe en baie geringe brein beserings veroorsaak kon word.

8. Beskrywing van die aard van die ongerief of gevare of waarskynlike permanente nagevolge vir proefpersone wat met die projek/proef gepaard mag gaan:

Daar is geen gevare of risiko's verbonde aan die studie buiten die risiko's verbonde aan die spel rugby wat gespeel word. Al die neuropsigologiese toetse is veilig en behels grootliks die toetsing van geheue en konsentrasie vermoëns. Die enigste ongerief aan die hele studie is die geduld wat spelers/proefpersone moet hê na elke wedstryd om vir ongeveer 15 minute hul samewerking te gee om die vraelys en toetse af te lê. Verder geensins enige aard van ongerief of gevaar nie.

9. Voorsorg wat getref word om proefpersone te beskerm:

Die voorsorg wat getref word om die proefpersoon/rugbyspeler te beskerm tydens wedstryde is die voorneme dat ek 'n opgeleide Biokinetikus en Dr. Paul Dijkstra 'n Sport Geneeskundige die nodige noodhulp of behandeling aan besering wat gekoppel word aan die kontak sport te hanteer. By die afneem van die voor- en na-seisoense toetsings sal opgeleide Sielkundiges die neuropsigologiese toetse afneem in samewerking met die Potchefstroomse Universiteit.

10. Beskrywing van die voordele wat uit die resultate van die proef verwag kan word:

Die voordele wat uit die studie verwag kan word is:

- Die vas stel van wat die insedensie van geringe en baie geringe traumatiese brein beserings in sekondêre skole rugby is.
- Om vas te stel of daar enige gevolge van geringe en baie geringe traumatiese brein beserings by sekondêre skole rugbyspelers is.
- As daar enige gevolge is, te gaan kyk hoe die spel nog veiliger gemaak kan word.

Handtekening van projekleier: ____________________ Datum: ________________

DEEL 2

Aan die ondertekenaar wat die toestemming vervat in die dokument:

Dit is belangrik dat u die volgende algemene beginsels wat op deelnemers aan ons navorsingsprojek van toepassing is, sal lees en verstaan:

1. Deelname aan die projek/proef is heeltemal vrywillig.
2. Dit is moontlik dat u persoonlik nie enige voordeel uit u deelname aan die projek/proef sal trek nie, alhoewel die kennis wat deur middel van die projek/proef opgedoen mag word andere tot voordeel kan strek.
3. Dit staan u vry om u self te enige tyd aan die projek/proef te onttrek. U word egter vriendelik versoek om nie sonder deeglike besinning aan die projek/proef te onttrek nie, aangesien dit o.a. die statistiese betroubaarheid van die projek/proef nadelig mag beïnvloed.
4. 'n Samevatting van die aard van die projek/proef, die vermeende risikofaktore, faktore wat moontlik ongerief of ongemak vir u kan veroorsaak, die voordele wat verwag kan word en die bekende en/of waarskynlike permanente nagevolge wat u deelname aan die projek/proef op u proefpersoon mag hê, word in Deel 1 hiervan vervat.
5. U word aangemoedig om op enige stadium enige vrae wat u in verband met die projek/proef en die prosedures in verband daarmee mag hê aan die projekleier of sy personeel te stel, wat u navrae graag sal beantwoord. Hulle sal ook die projek/proef volledig met u bespreek.
6. Indien u minderjarig is, is die skriftelike toestemming van u ouer of wettige voog nodig alvorens u aan die projek mag deelneem.

Met Dank,

Rines Laubscher

Dr. Paul Dijkstra

Ingeligte toestemmings brief: (Kontrole groep)

U word uitgenooi om as kontrole deel te neem aan die navorsingsprojek van Rines Laubscher tot die doel vir die verwerwing van sy Doktoraal (PhD):

Titel van projek:

THE NEUROPSYCHOLOGICAL AND ACADEMIC CONSEQUENCES OF REPEATED MILD AND VERY MILD TRAUMATIC BRAIN INJURIES IN RUGBY AT A SECONDARY SCHOOL

Ek, die ondergetekende ____ (volle name en van) het die gegewens in verband met die projek/proef genoem in Deel 1 en Deel 2 hiervan gelees en ook die mondelinge weergawe daarvan aangehoor en ek verklaar dat ek dit verstaan. Ek was die geleentheid gegun om tersaaklike aspekte van die projek/proef met die projekleier te bespreek en ek verklaar hiermee dat ek vrywillig aan die projek/proef deelneem. Ek gee hiermee my toestemming om as proefpersoon (kontrole groep) in bogenoemde projek op te tree. Ek vrywaar hiermee die Universiteit asook enige werknemer of student van die Universiteit, teen enige aanspreeklikheid wat teenoor my, in die loop van die projek/proef mag ontstaan. Ek onderneem verder om geen eise teen die Universiteit in te stel weens skade of persoonlikheidsnadeel wat ek weens die projek/proef mag ly nie, hetsy dit aan die nalatigheid van die Universiteit, sy werknemers of studente, of ander proefpersone mag ontstaan nie.

____

(Handtekening van proefpersoon [kontrole groep])

Onderteken te __________________________ op __________________________

GETUIES

1. __________________________________
2. __________________________________

Onderteken te ______________________________ op ______________________________

Proefpersone (kontrole groep) onder die ouderdom van 21 jaar is die skriftelike toestemming van die ouer of wettige voog ook nodig:

Hiermee gee ek ____
(Volle name en van) ouer / wettige voog van die proefpersoon hierbo genoem toestemming dat hy/sy aan hierdie projek/proef mag deelneem en ek vrywaar hiermee die Universiteit asook enige werknemer of student van die Universiteit, teen enige aanspreeklikheid wat teenoor my in die loop van die projek/proef mag ontstaan.

Handtekening: ______________________________ Datum: ______________________________

Verwantskap: ______________________________

DEEL 1

Inligting tot die navorsingstudie:

1. **Skool (vakgroep)/Instituut:** Skool vir Biokinetika, Rekreasie en Sport Wetenskap.
2. **Titel van projek/proef:** The neuropsychological and academical consequences of repeated mild and very mild traumatic brain injuries in rugby at a secondary school
3. **Volle name, van en kwalifikasies van projekleier/navorser:** Prof. H.P. Dijkstra, M.B.Ch.B., B.Sc. Hons.
4. **Rang/pos van projekleier/navorser:** Lektor by Noord-Wes Universiteit, Potchefstroom Kampus.
5. **Naam van toesighoudende geneesheer (waar van toepassing):** Dr. Paul Dijkstra.
6. **Die doel van die projek:**

- Om die insedensie van geringe (harsingskudde) en baie geringe (ligte kop stampe) brein besering in rugby op sekondêre skole vlak te rapporteer.
- Om die moontlike gevolge van geringe en baie geringe brein besering in rugby spelers op sekondêre skole vlak vas te stel deur gebruik te maak van neuropsigologiese toetse.
- Om vas te stel wat se effek geringe en baie geringe brein beserings op rugby spelers op sekondêre skole vlak se akademiese werk het.

7. **Verduideliking van die aard van alle prosedures wat gevolg sal word, insluitende identifisering van nuwe prosedures:**

   Fase 1 van die studie is die voltooiing van die ingeligte toestemmings vorms en 'n vraelys waarin die demografiese inligting van die proefpersoon (kontrole groep) weergegee word asook relevante inligting ten opsigte van die studie. 'n Voor-seisoense toetsing word deur middel van neuropsigologiese toetse gedoen. Aan die einde van die rugby seisoen sal elke speler (kontrole groep) weer 'n eind toetsing deur middel van neuropsigologiese toetse ondergaan. Die proefpersone (kontrole groep) se akademiese rekords sal dan by die skool aangevra word en deur gegaan word om vas te stel of daar enige effek is wat moontlik deur geringe en baie geringe brein beserings by die rugby spelers voorkom. Dit wil sê die rugby spelers word met die kontrole groep vergelyk.

8. **Beskrywing van die aard van die ongerief of gevare of waarskynlike permanente nagevolge vir proefpersone wat met die projek/proef gepaard mag gaan:**
   Daar is geen gevare of risiko's verbonde aan die studie nie. Al die neuropsigologiese toetse is veilig en behels grootliks die toetsing van geheue en konsentrasie vermoëns. Die toetsing duur ongeveer 'n uur lank.
9. **Voorsorg wat getref word om proefpersone te beskerm:**
   Die voorsorg wat getref word om die proefpersoon (kontrole groep) te beskerm is om al die inligting so professioneel en vertroulik as moontlik te hanteer. By die afneem van die voor- en na-seisoense toetsings sal opgeleide Sielkundiges die neuropsigologiese toetse afneem in samewerking met die Noord-Wes Universiteit, Potchefstroom Kampus.
   Beskrywing van die voordele wat uit die resultate van die proef verwag kan word:
   Die voordele wat uit die studie verwag kan word is:

- Die vas stel van wat die insedensie van geringe en baie geringe brein beserings in sekondêre skole rugby is.
- Om vas te stel of daar enige gevolge van geringe en baie geringe brein beserings by sekondêre skole rugbyspelers is.
- As daar enige gevolge is, te gaan kyk hoe die spel nog veiliger gemaak kan word.

Handtekening van projekleier: ____________________ Datum: ________________

DEEL 2

Aan die ondertekenaar wat die toestemming vervat in die dokument:

Dit is belangrik dat u die volgende algemene beginsels wat op deelnemers aan ons navorsingsprojek van toepassing is, sal lees en verstaan:

1. Deelname aan die projek/proef is heeltemal vrywillig.
2. Dit is moontlik dat u persoonlik nie enige voordeel uit u deelname aan die projek/proef sal trek nie, alhoewel die kennis wat deur middel van die projek/proef opgedoen mag word andere tot voordeel kan strek..
3. Dit staan u vry om u self te enige tyd aan die projek/proef te onttrek. U word egter vriendelik versoek om nie sonder deeglike besinning aan die projek/proef te onttrek nie, aangesien dit o.a. die statistiese betroubaarheid van die projek/proef nadelig mag beïnvloed.
4. 'n Samevatting van die aard van die projek/proef, die vermeende risikofaktore, faktore wat moontlik ongerief of ongemak vir u kan veroorsaak, die voordele wat verwag kan word en die bekende en/of waarskynlike permanente nagevolge wat u deelname aan die projek/proef op u proefpersoon mag hê, word in Deel 1 hiervan vervat.
5. U word aangemoedig om op enige stadium enige vrae wat u in verband met die projek/proef en die prosedures in verband daarmee mag hê aan die projekleier of sy personeel te stel, wat u navrae graag sal beantwoord. Hulle sal ook die projek/proef volledig met u bespreek.
6. Indien u minderjarig is, is die skriftelike toestemming van u ouer of wettige voog nodig alvorens u aan die projek mag deelneem.

Met Dank,

______________	______________
Rines Laubscher	Dr. Paul Dijkstra

The Standardised Assessment of Concussion (SAC)

Subtest:	Procedure:	Scoring:
1. Orientation	The player is asked to provide the date, day of the week, month, year and time of day (within 1 hour).	Each correct answer scores 1, with the total scoring being out of 5.
2. Immediate memory	The player is asked to recall 5 words immediately after they have been read to the player. Three trials are completed.	Each correct recalled word is scored out of 1, with the total scoring being out of 15.
3. Neurological screening	The sport doctor as part of his standardised assessment completes this.	No scoring as the components are merely commented on.
4. Concentration: digits backwards	The player is asked to repeat a string of digits that increase in length from 3 to 6 numbers in reverse.	It consists of two trials, allowing the player two chances. This test is scored out of 4.
5. Concentration: months in reverse order	The player is asked to recite the entire sequence of the months of the year in reverse order.	This test is scored out of 1. Entire sequence must be correct. Total task is scored out of 5.
6. Exertional manoeuvres	The player is asked to perform one 40-yard sprint, 5 jumping jacks, 5 sit-ups and 5 push-ups. (If appropriate).	This component is merely commented on.

SAC

Standardized Assessment of Concussion

Form A

McCrea, Kelly, Randolph

Name: ____________________

Date of Exam:________Time: ________

Examiner: ____________________

1. ORIENTATION: (1 point each)

Month: ____________	0	1
Date: ____________	0	1
Day of week: ____________	0	1
Year: ____________	0	1
Time (within 1 hr.): ____________	0	1

Orientation Total Score _______/ 5

2. IMMEDIATE MEMORY:

(1 point for each correct, total over 3 trials)

Immediate Memory Total Score ___/ 15

List	Trial 1	Trial 2	Trial 3
Elbow			
Apple			
Carpet			
Saddle			
Bubble			
Total			

NEUROLOGICAL SCREENING:

Strength:

Sensation:

Coordination:

3. CONCENTRATION:

Reverse Digits: (Go to next string length if correct on first trial. Stop if incorrect on both trials.1pt. For each string length)

4-9-3	6-2-9	0	1
3-8-1-4	3-2-7-9	0	1
6-2-9-7-1	1-5-2-8-6	0	1
7-1-8-4-6-2	5-3-9-1-4-8	0	1

Months in reverse order: (1pt. for entire sequence correct)

Dec-Nov-Oct-Sep-Aug-Jul
Jun-May-Apr-Mar-Feb-Jan 0 1

Concentration Total Score ____/ 5

EXERTIONAL MANEUVERS

(When appropriate):

1 20-yard sprint	5 push-ups
5 sit-ups	5 knee-bends

4. DELAYED RECALL: (1 pt. each)

Elbow	0	1
Apple	0	1
Carpet	0	1
Saddle	0	1
Bubble	0	1

Delayed Recall Total Score ___/ 5

SUMMARY OF TOTAL SCORES:

Orientation	______/ 5
Immediate Memory	______/ 15
Concentration	______/ 5
Delayed Recall	______/ 5
Total Score	______/ 30

SAC

Standardized Assessment of Concussion

Form B

McCrea, Kelly, Randolph

Name: ______________________________

Date of Exam:________**Time:** ________

Examiner: ____________________________

1. ORIENTATION: (1 point each)

Month: __________________ 0 1

Date: ____________________ 0 1

Day of week: ______________ 0 1

Year: ____________________ 0 1

Time (within 1 hr.): ___________ 0 1

Orientation Total Score _______/ 5

2. IMMEDIATE MEMORY:

(1 point for each correct, total over 3 trials)

Immediate Memory Total Score ___/ 15

List	Trial 1	Trial 2	Trial 3
Candle			
Paper			
Sugar			
Sandwich			
Wagon			
Total			

NEUROLOGICAL SCREENING:

Strength:

Sensation:

Coordination:

3. CONCENTRATION:

Reverse Digits: **(Go to next string length if correct on first trial. Stop if incorrect on both trials.1pt. For each string length)**

5-2-6	4-1-5	0	1
1-7-9-5	4-9-6-8	0	1
4-8-5-2-7	6-1-8-4-3	0	1
8-3-1-9-6-4	7-2-4-8-5-6	0	1

Months in reverse order: **(1pt. for entire sequence correct)**

Dec-Nov-Oct-Sep-Aug-Jul

Jun-May-Apr-Mar-Feb-Jan 0 1

Concentration Total Score ____/ 5

EXERTIONAL MANEUVERS

(When appropriate):

1 20-yard sprint	5 push-ups
5 sit-ups	5 knee-bends

4. DELAYED RECALL: (1 pt. each)

Candle	0	1
Paper	0	1
Sugar	0	1
Sandwich	0	1
Wagon	0	1

Delayed Recall Total Score ____/ 5

SUMMARY OF TOTAL SCORES:

Orientation	_______/ 5
Immediate Memory	_______/ 15
Concentration	_______/ 5
Delayed Recall	_______/ 5
Total Score	_______/ 30

SAC

Standardized Assessment of Concussion

Form C

McCrea, Kelly, Randolph

Name: ______________________

Date of Exam:________**Time:** ________

Examiner: ______________________

1. ORIENTATION: (1 point each)

Month: ______________	0	1
Date: ______________	0	1
Day of week: ______________	0	1
Year: ______________	0	1
Time (within 1 hr.): ______________	0	1

Orientation Total Score _______/ 5

2. IMMEDIATE MEMORY:

(1 point for each correct, total over 3 trials)

Immediate Memory Total Score ____/ 15

List	Trial 1	Trial 2	Trial 3
Baby			
Monkey			
Perfume			
Sunset			
Iron			
Total			

NEUROLOGICAL SCREENING:

Strength:

Sensation:

Coordination:

3. CONCENTRATION:

Reverse Digits: (Go to next string length if correct on first trial. Stop if incorrect on both trials. 1pt. For each string length)

1-4-2	6-5-8	0	1
6-8-3-1	3-4-8-1	0	1
4-9-1-5-3	6-8-2-5-1	0	1
3-7-6-5-1-9	9-2-6-5-1-4	0	1

Months in reverse order: (1pt. for entire sequence correct)

Dec-Nov-Oct-Sep-Aug-Jul
Jun-May-Apr-Mar-Feb-Jan 0 1

Concentration Total Score ____/ 5

EXERTIONAL MANEUVERS

(When appropriate):

1 20-yard sprint	5 push-ups
5 sit-ups	5 knee-bends

4. DELAYED RECALL: (1 pt. each)

Baby	0	1
Monkey	0	1
Perfume	0	1
Sunset	0	1
Iron	0	1

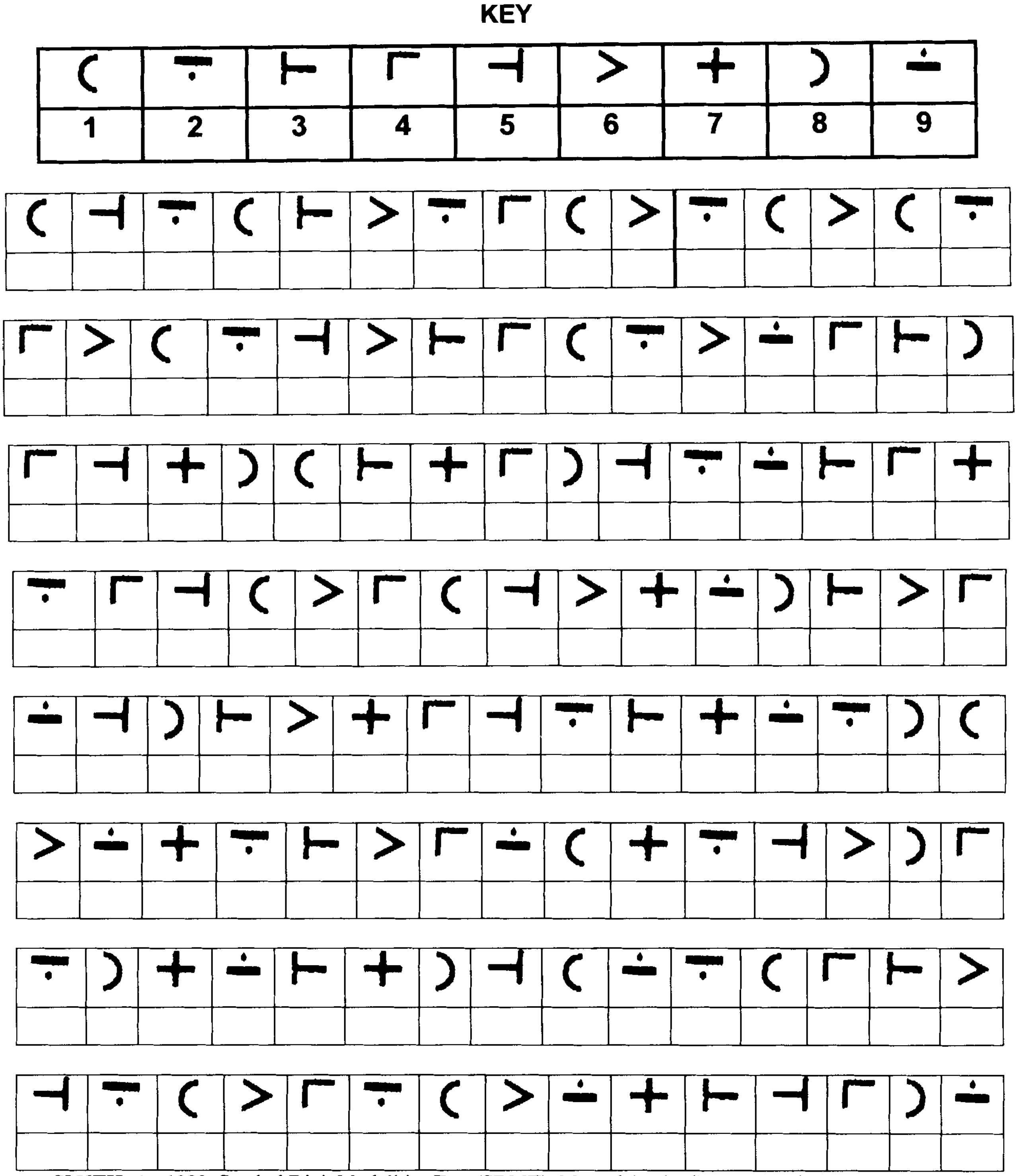
Delayed Recall Total Score ____/ 5

SUMMARY OF TOTAL SCORES:

Orientation	______/ 5
Immediate Memory	______/ 15
Concentration	______/ 5
Delayed Recall	______/ 5
Total Score	______/ 30

SYMBOL DIGIT MODALITIES TEST

Name: ____________________________ **Date:** ________________



SMITH, A. 1982. Symbol Digit Modalities Test (SDMT). Manual (revised). Los Angeles: Western Psychological Services.

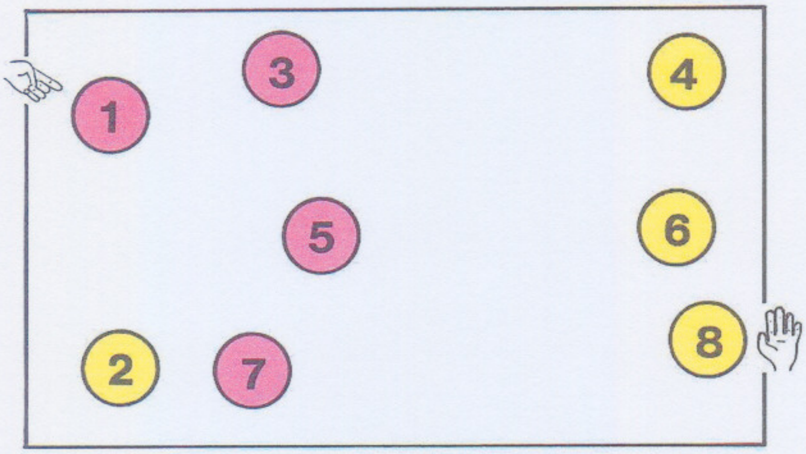
Color Trails 1

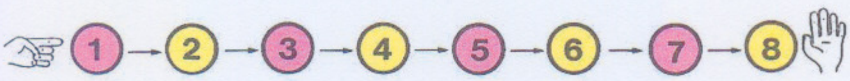
by Louis F. D'Elia, PhD, and Paul Satz, PhD

Form A

Name: ______________________________

ID#: __________________ Date: ___________





PAR Psychological Assessment Resources, Inc./P.O. Box 998/Odessa, FL 33556/Toll-Free 1-800-331-TEST

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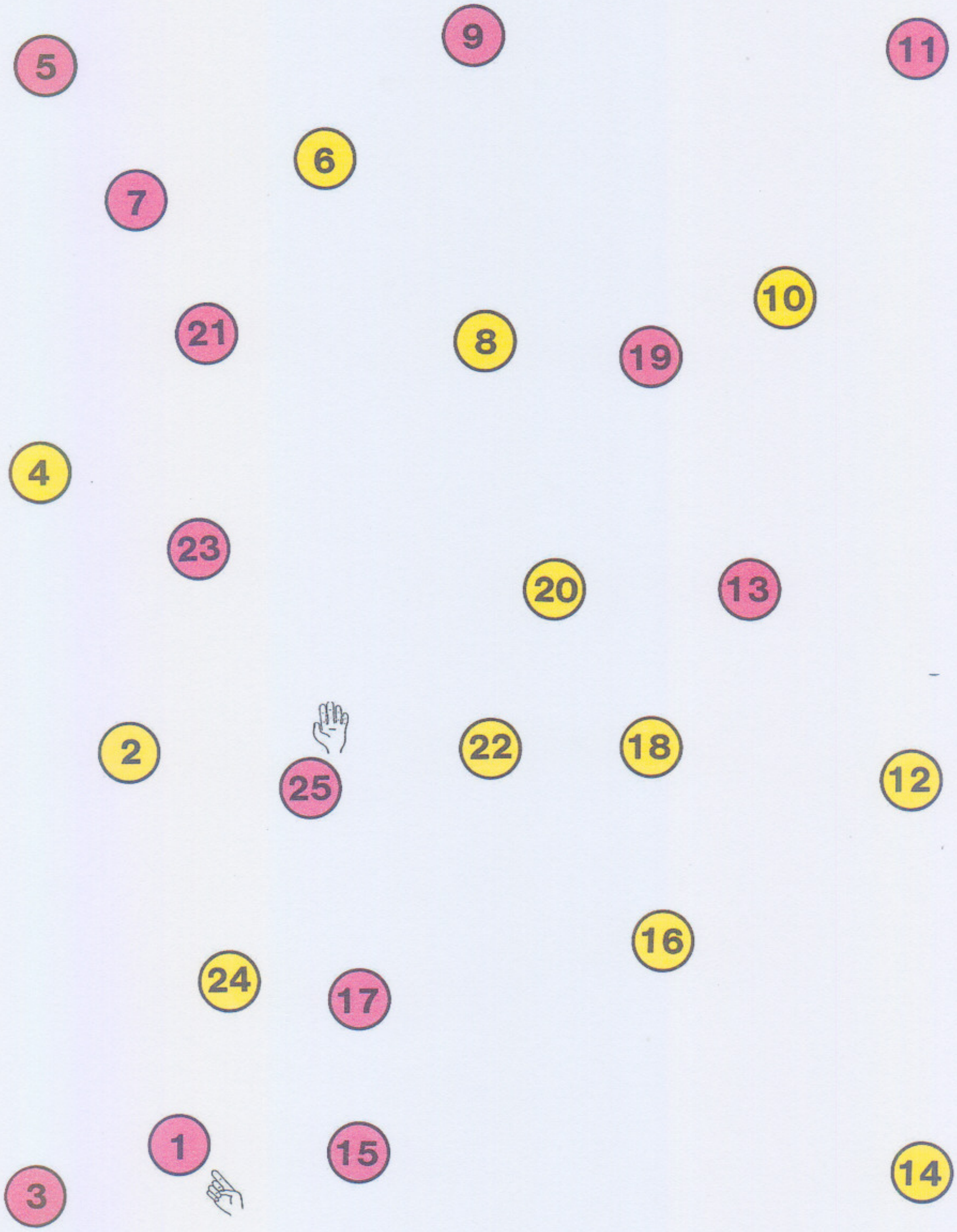
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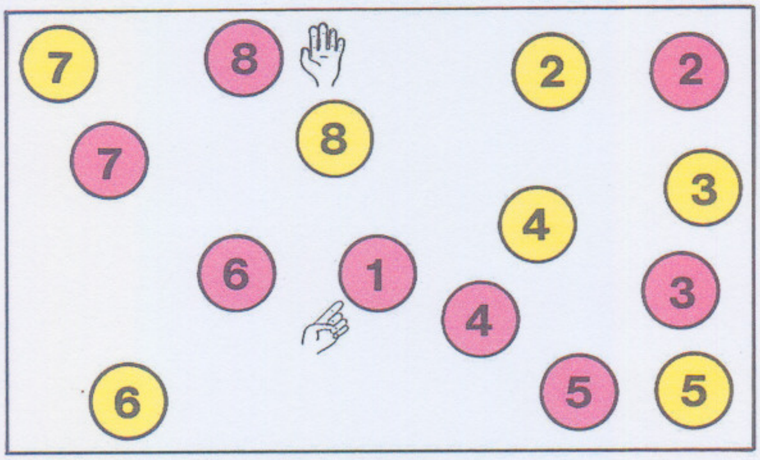
Color Trails 2

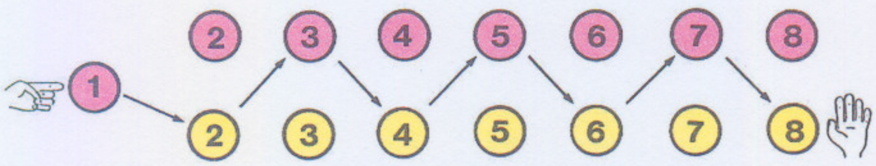
by Louis F. D'Elia, PhD, and Paul Satz, PhD

Form A

Name: ______________________________

ID#: ________________ Date: __________





PAR Psychological Assessment Resources, Inc./P.O. Box 998/Odessa, FL 33556/Toll-Free 1-800-331-TEST

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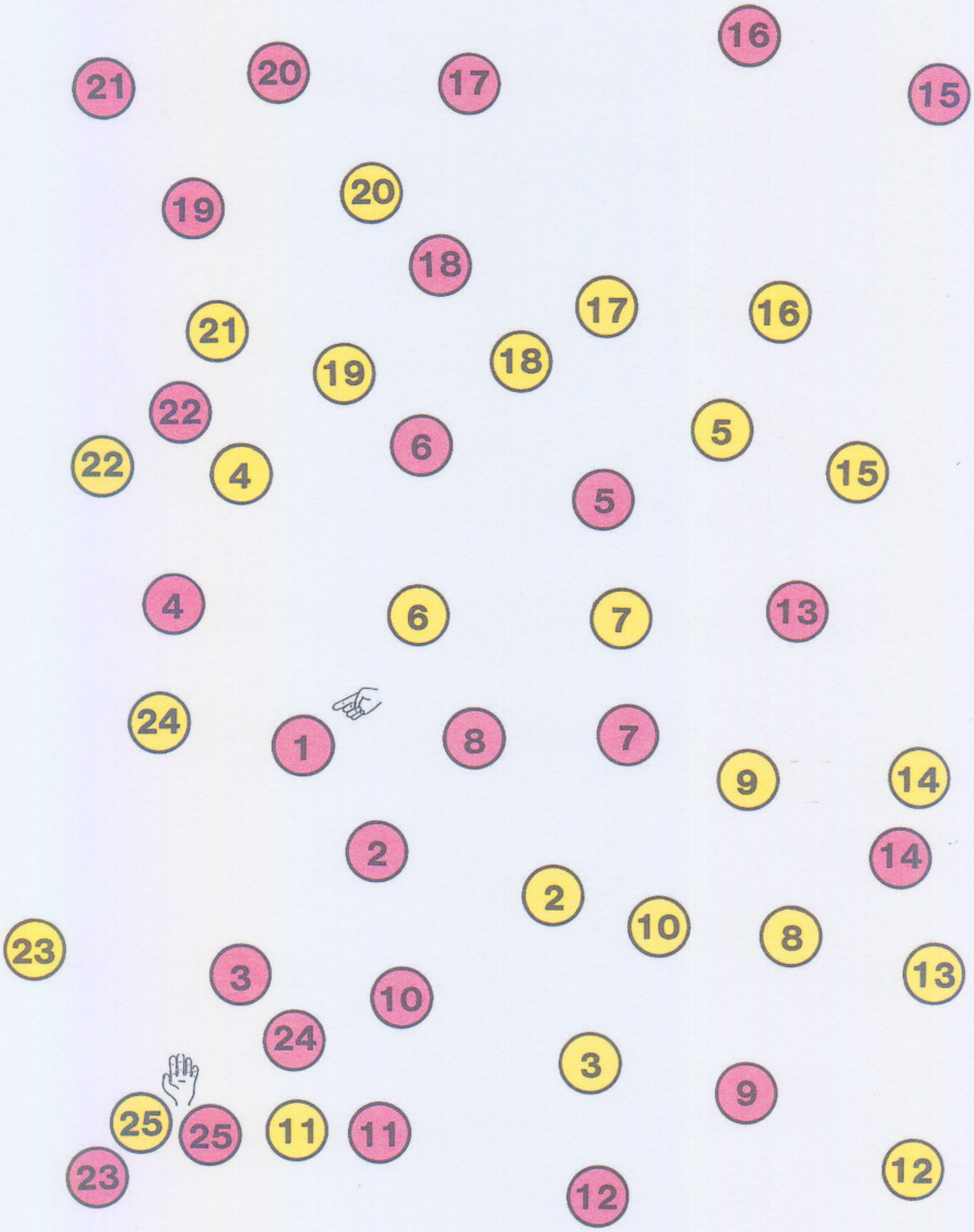
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WECHSLER MEMORY SCALE – REVISED (WMS-R): (Wechsler, 1987)

The Wechsler Memory Scale-Revised comprises a series of brief subtests, each measuring a different facet of memory (Wechsler, 1987). The following subtests with their different measuring facets were used:

- Information and orientation questions

  This subtest contains simple questions covering biographical data, orientation and common information from long-term memory. Questions 1 to 7 ask the examinee's name and other relative information. Questions 8 to 14 concern the individual's orientation in time (date, time of day) and place (Locality, place of testing). The last two questions concern the individual's hand preference and whether he or she has any impairments of hearing or vision that could influence performance on some of the WMS-R subtests (Wechsler, 1987).

- Mental control

  The three items of this subtest are, counting backward from 20 to 1, record the time in seconds. The time limit is 30 seconds. Name the alphabet; record the time in seconds. The time limit is 30 seconds. Counting by 3's, record the time in seconds. The time limit is 45 seconds (Wechsler, 1987). This subtest will test the subject's memory and concentration levels.

- Figural memory

  This subtest measures memory for figural stimuli. Figural memory involves showing the examinee a set of abstract designs. Then, after each set of designs are removed, the examinee is asked to identify the designs within a larger set of designs (Wechsler, 1987).

- Logical memory I (Immediate recall)

  This subtest consists of two brief stories that are read to the examinee. After each story, the examinee retells the story from memory (Wechsler, 1987).

- Visual paired associates I (Immediate recall)

  This subtest requires the examinee to learn the colour associated with each of six abstract line drawings. In order to minimise the role of verbal mediation in memorising and responding to the figure-colour pairs, the colour names are not used either in presenting the items or in responding to them. The pairs are presented until the examinee answers all six items correctly; however, only the first three presentations are scored, and no more than six presentations are given. Using six presentations insures that the examinees learn the material to the criterion of one perfect repetition (Wechsler, 1987).

- Verbal paired associates I (Immediate recall)

  In this subtest a group of eight word pairs are read to the examinee, then the first word of each pair is read, and then the examinee is asked to supply the second word from his memory. Only the first three presentations are scored, although six presentations are given (Wechsler, 1987).

- Visual reproduction I (Immediate recall)

  The examinee looks at a geometric design and is then asked to draw it from memory (Wechsler, 1987).

- Digit span

  The two parts of the Digit Span subtest, 'Digits Forward' and 'Digits Backward', are administered separately. On 'Digits Forward', number sequences of increasing length are read to the examinee, after each sequence the examinee is asked to repeat it from memory. On 'Digits Backward', similar number sequences are read to the examinee, and after each sequence the examinee is asked to repeat it backwards. Administer 'Digits Backward' even if the examinee does poorly on 'Digits Forward' (Wechsler, 1987).

- Visual Memory Span

  The two parts of the Visual Memory Span subtest, Tapping Forward and Tapping Backward are administered separately. In Tapping Forward the examinee watches the examiner touch the red squares on Card 1 in sequences of increasing length, and after each sequence is asked to repeat the performance from memory. In Tapping Backward the examinee watches the examiner touch the green squares on Card 2 in sequences of increasing length, and is asked to repeat the performance in reverse. Administer Tapping Backward even if the examinee does poorly on Tapping Forward (Wechsler, 1987).

- Logical Memory II (Delayed recall)

  Administer this subtest at least 30 minutes after completion of Logical Memory I. If necessary, pause after Visual Memory Span to ensure that at least 30 minutes have elapsed (Wechsler, 1987).

- Visual Paired Associates II (Delayed recall)

  Administer this subtest at least 30 minutes after completion of Visual Paired Associates I (Wechsler, 1987).

- Verbal Paired Associates II (Delayed recall)

  Administer this subtest at least 30 minutes after completion of Verbal Paired Associates I (Wechsler, 1987).

- Visual Reproduction II (Delayed recall)

  Administer this subtest at least 30 minutes after completion of Visual Reproduction I (Wechsler, 1987).

WMS-R

Wechsler
Memory Scale-Revised

RECORD FORM

Name ______________________________

Sex ____________ Education ____________________

Place of Testing ______________________________

Examiner ______________________________

Reason for Referral ______________________________

____

____

	Year	Month	Day
Date of Testing	___	___	___
Date of Birth	___	___	___
Age	___	___	___

SUBTEST RAW SCORES AND INDEXES

Subtest	Raw Score	Weight	Verbal Memory	Visual Memory	General Memory	Attention/ Concentration	Delayed Recall
Information and Orientation	___						
Mental Control	___	x1				___	
Figural Memory	___	x1		___			
Logical Memory I	___	x2	___				
Visual Paired Associates I	___	x1		___			
Verbal Paired Associates I	___	x1	___				
Visual Reproduction I	___	x1		___			
Digit Span	___	x2				___	
Visual Memory Span	___	x2				___	
Logical Memory II	___	x1					___
Visual Paired Associates II	___	x2					___
Verbal Paired Associates II	___	x2					___
Visual Reproduction II	___	x1					___
Weighted Raw Score Sums			☐ +	☐ =	☐	☐	☐
Indexes			☐	☐	☐	☐	☐

This subtest is not used in the calculation of any of the Indexes

THE PSYCHOLOGICAL CORPORATION
HARCOURT BRACE JOVANOVICH, INC.

INFORMATION AND ORIENTATION QUESTIONS Administer all items exactly as worded		Score
Questions	Responses	1 or 0
1. What is your full name?		
2. How old are you?		
3. When were you born?		
4. Where were you born?		
5. What is your mother's first name?		
6. Who is the President of United States?		
7. Who was President before?		
8. What year is this?		
9. What month is this?		
10. What day of the month is this?		
11. What is the name of the place you are in?		
12. In what city is this?		
13. What day of the week is this?		
14. What time is it now?		
15. Are you left-handed or right handed?		
16. Do you have any difficulty in hearing?		
17. Do you need glasses for reading?		
18. Are you color-blind?		
	Max. = 14 Total	

MENTAL CONTROL Administer all items.			
Item	Time	Errors	Score 2,1 or 0
1. (30sec.) 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1			
2. (30 sec.) A B C D E F G H I J K L M N O P Q R S T U V W X Y Z			
3. (45 sec.) 1 4 7 10 13 16 19 22 25 28 31 34 37 40			
		Max. = 6 Total	

FIGURAL MEMORY	Administer all items.		
Item	Key	Response	Score 1 or 0
1	1		
2	3,5,8		Score 3,2,1, or 0
3	1,6,7		
4	2,4,9		
		Max. = 10 Total	

WMS-R

Logiese Geheue I & II:

Administreer beide stories. Ken 1 punt per korrekte antwoord toe.

Storie A

Anna / Swart, / van Kwazulu / Natal, / wat as 'n skoonmaker / werk / in 'n restaurant / se kombuis, / het by die stad / se Polisiekantoor / 'n klag ingedien / dat sy aangehou is / in kerkstraat / die vorige aand, / en beroof is / van ses-en-vyftig rand. / Sy het vier / klein kindertjies, / haar huur moet betaal word, / en hulle het die afgelope twee dae / nie geëet nie. / Die polisie, / wat geraak is deur haar storie, / het geld ingesamel / vir die vrou.

Totaal Storie A: __________ (Maks. = 25)

Storie B

Riaan / Nel / het een nag / 'n tien ton / vragmotor, / wat eiers vervoer, / bestuur / op die hoofweg / in die Witwatersrand / omgewing, / op pad na Kaapstad, / toe sy as / breek. / Sy vragmotor het gegly / van die pad af / tot in 'n sloot. / Hy is teen die windskerm / geslinger / en was baie geskok. / Daar was geen verkeer nie / en hy het getwyfel of hulp sou opdaag. / Toe het sy gesels-radio / gelui. / Hy het vinnig geantwoord: / "Dit is Sprinkaan wat praat."

Totaal Storie B: __________ (Maks. = 25)

Totaal Storie A + B: __________ (Maks. = 50) **Horlosietyd: __________**

VISUAL PAIRED ASSOCIATES I				If the examinee answers all six items correctly on Set III, discontinue the subtest. Otherwise, present Sets IV, V and VI until all six items are correct.							
SET I				SET II				SET III			
Item	Key	Response	Score 1 or 0	Item	Key	Response	Score 1 or 0	Item	Key	Response	Score 1 or 0
1	G			1	Y			1	B		
2	Pu			2	R			2	G		
3	R			3	B			3	Pu		
4	Y			4	Pu			4	Pk		
5	Pk			5	G			5	Y		
6	B			6	Pk			6	R		
		Set I Total				Set II Total				Set III Total	
										Max. = 18 Total Sets I-III	

SET IV				SET V				SET VI			
Item	Key	Response	Score 1 or 0	Item	Key	Response	Score 1 or 0	Item	Key	Response	Score 1 or 0
1	G			1	Pu			1	G		
2	Pu			2	B			2	Y		
3	R			3	Y			3	B		
4	Y			4	Pk			4	R		
5	Pk			5	R			5	Pu		
6	B			6	G			6	Pk		
		Set IV Total				Set V Total				Set VI Total	

VERBAL PAIRED ASSOCIATES I   If the examinee answers all eight items correctly on the third set, discontinue the subtest. Otherwise, present Sets IV, V and VI until all eight items are correct.

SET I	Recall	Easy	Hard
Metal-Iron	Fruit	______	
Baby-Cries	Obey		______
Crush-Dark	Rose	______	
School-Grocery	Baby	______	
Rose-Flower	Cabbage		______
Obey-Inch	Metal	______	
Fruit-Apple	School		______
Cabbage-Pen	Crush		______
	Total	______	______

SET II	Recall	Easy	Hard
Rose-Flower	Cabbage		______
Cabbage-Pen	Baby	______	
Obey-Inch	Metal	______	
Fruit-Apple	School		______
School-Grocery	Rose	______	
Metal-Iron	Crush		______
Crush-Dark	Fruit	______	
Baby-Cries	Obey		______
	Total	______	______

SET III	Recall	Easy	Hard
Baby-Cries	Obey		______
Crush-Dark	Fruit	______	
School-Grocery	Baby	______	
Rose-Flower	Metal	______	
Cabbage-Pen	Crush		______
Fruit-Apple	School		______
Obey-Inch	Rose	______	
Metal-Iron	Cabbage		______
	Total	______	______

SET IV	Recall	Easy	Hard
Crush-Dark	School		______
Cabbage-Pen	Metal	______	
Fruit-Apple	Obey		______
Obey-Inch	Crush		______
Baby-Cries	Fruit	______	
Rose-Flower	Baby	______	
Metal-Iron	Cabbage		______
School-Grocery	Rose	______	
	Total	______	______

SET V	Recall	Easy	Hard
Fruit-Apple	Rose	______	
School-Grocery	Crush		______
Rose-Flower	Baby	______	
Cabbage-Pen	Metal	______	
Metal-Iron	Obey		______
Crush-Dark	Cabbage		______
Baby-Cries	School		______
Obey-Inch	Fruit	______	
	Total	______	______

SET VI	Recall	Easy	Hard
Metal-Iron	Baby	______	
Rose-Flower	Fruit	______	
Crush-Dark	Cabbage		______
Baby-Cries	Rose	______	
Obey-Inch	School		______
Fruit-Apple	Obey		______
Cabbage-Pen	Crush		______
School-Grocery	Metal	______	
	Total	______	______

Total Sets I-III	Max. Easy = 12	Max. Hard = 12	Max. Total = 24	

VISUAL REPRODUCTION I Use VRI Copying Sheet.		
Hand used: ________ Right ________ Left		
Item	Score (see Visual Reproduction Scoring Summary)	
1		Observations:
2		
3		
4		
Max. = 41 Total		

DIGIT SPAN Discontinue after failure on both trials of any item. Administer both trials of each item, even if the first trial is passed.					
DIGITS FORWARD					Score
Item	Trial I	Pass-Fail	Trial II	Pass-Fail	2, 1, or 0
1.	6-2-9		3-7-5		
2.	5-4-1-7		8-3-9-6		
3.	3-6-9-2-5		6-9-4-7-1		
4.	9-1-8-4-2-7		6-3-5-4-8-2		
5.	1-2-8-5-3-4-6		2-8-1-4-9-7-5		
6.	3-8-2-9-5-1-7-4		5-9-1-8-2-6-4-7		
				Max. = 12 Total Forward	
DIGITS BACKWARD Administer Digits Backward even if examinee scores 0 on Digits forward.					Score
Item	Trial I	Pass-Fail	Trial II	Pass-Fail	2, 1, or 0
1.	5-1		3-8		
2.	4-9-3		5-2-6		
3.	3-8-1-4		1-7-9-5		
4.	6-2-9-7-2		4-8-5-2-7		
5.	7-1-5-2-8-6		8-3-1-9-6-4		
6.	4-7-3-9-1-2-8		8-1-2-9-3-6-5		
		Max. = 12 Total Backward		Max. Total = 24	

VISUAL MEMORY SPAN	Discontinue after failure on both trials of any item. Administer both trials of each item, even if the first trial is passed.				
TAPPING FORWARD					Score
Item	Trial I	Pass-Fail	Trial II	Pass-Fail	2, 1, or 0
1.	2-6		8-4		
2.	2-7-5		8-1-6		
3.	3-2-8-4		2-6-1-5		
4.	5-3-4-6-1		3-5-1-7-2		
5.	1-7-2-8-5-4		7-3-6-1-4-8		
6.	8-2-5-3-4-1-6		4-2-6-8-3-7-5		
7.	7-5-6-3-8-7-4-2		1-6-7-4-2-8-5-3		
				Max. = 14 Total Forward	
TAPPING BACKWARD	Administer Tapping Backward even if examinee scores 0 on Tapping Forward.				Score
Item	Trial I	Pass-Fail	Trial II	Pass-Fail	2, 1, or 0
1.	3-6		7-4		
2.	6-8-5		3-1-8		
3.	8-4-1-6		5-2-4-1		
4.	4-6-8-5-2		8-1-6-3-7		
5.	7-1-8-3-6-2		3-8-1-7-5-4		
6.	1-5-2-7-4-3-8		6-7-4-3-1-5-2		
		Max. = 12 Total Backward		Max. Total = 26	

WMS-R

Logiese Geheue I & II:

Administreer beide stories. Ken 1 punt per korrekte antwoord toe.

Storie A

Anna / Swart, / van Kwazulu / Natal, / wat as 'n skoonmaker / werk / in 'n restaurant / se kombuis, / het by die stad / se Polisiekantoor / 'n klag ingedien / dat sy aangehou is / in kerkstraat / die vorige aand, / en beroof is / van ses-en-vyftig rand. / Sy het vier / klein kindertjies, / haar huur moet betaal word, / en hulle het die afgelope twee dae / nie geëet nie. / Die polisie, / wat geraak is deur haar storie, / het geld ingesamel / vir die vrou.

Totaal Storie A: __________ (Maks. = 25)

Storie B

Riaan / Nel / het een nag / 'n tien ton / vragmotor, / wat eiers vervoer, / bestuur / op die hoofweg / in die Witwatersrand / omgewing, / op pad na Kaapstad, / toe sy as / breek. / Sy vragmotor het gegly / van die pad af / tot in 'n sloot. / Hy is teen die windskerm / geslinger / en was baie geskok. / Daar was geen verkeer nie / en hy het getwyfel of hulp sou opdaag. / Toe het sy gesels-radio / gelui. / Hy het vinnig geantwoord: / "Dit is Sprinkaan wat praat."

Totaal Storie B: __________ (Maks. = 25)

Totaal Storie A + B: __________ (Maks. = 50) **Horlosietyd: __________**

VISUAL PAIRED ASSOCIATES II			
Item	Key	Response	Score 1 or 0
1	Pk		
2	R		
3	G		
4	B		
5	Y		
6	Pu		
		Max. = 6 Total	

VERBAL PAIRED ASSOCIATES II			
Stimulus Word (and correct response	Response		
	Easy	Hard	
ROSE – (Flower)			
METAL – (Iron)	______		
SCHOOL – (Grocery)	______		
CABBAGE – (Pen)		______	
BABY – (Cries)		______	
CRUSH – (Dark)	______		
OBEY – (Inch)		______	
FRUIT – (Apple)		______	
	______		
Total	Max. = 4	Max. = 4	Max. Total = 8

VISUAL REPRODUCTION II Use VRII Copying Sheet.		
Hand used: ________ Right ________ Left		
Item	Score (see Visual Reproduction Scoring Summary)	
1		Observations:
2		
3		
4		
Max. = 41 Total		

VISUAL REPRODUCTION SCORING SUMMARY (see Appendix B in Manual for Scoring Criteria)

CARD A

	VR I	VR II
Staffs:		
1. Unbroken/straight/equal		
2. Intersect at midpoints		
3. Cross at right angles		
4. Not rotated (15 degrees)		
Flags:		
5. Correct direction		
6. Share side with staff		
7. Square in shape		
Total		

CARD B

	VR I	VR II
Circles:		
1. Large circle		
2. Medium circle inside large circle		
3. Small circle inside medium circle		
4. Large circle and medium circle touch (top)		
5. Small circle and medium circle touch (bottom)		
6. Round/closed		
7. Correct proportion		
Total		

CARD D

	VR I	VR II
Rectangles:		
1. Do not touch/intersect		
2. Interior angles 90 degrees		
3. Not rotated (15 degrees)		
4. 2 small to right of large		
5. Uppermost is taller		
6. Bases of large and small level		
7. Top of large higher than small		
8. Bases of 3 equally long		
9. Height of large > width		
10. Heights of small < width		
Circle Segments:		
11. Figure to right of rectangles		
12. Arc curves to right		
13. Symmetry/proportion		
14. Not rotated (15 degrees)		
Triangle:		
15. Figure to right of segment		
16. Vertex touches midpoint		
17. Contains 90 degrees angle		
18. Not rotated (15 degrees)		
Total		
Total (Cards A trough D) Max. = 41		

CARD C	Notes:
Large Square:	
1. Square in shape ______ ______	
2. Vertical & horizontal lines ______ ______	
3. Not rotated (15 degrees) ______ ______	
4. Each quadrant has 4 dots ______ ______	
Medium Squares:	
5. In 4 quadrants not touching ______ ______	
6. Square in shape ______ ______	
7. Vertical & horizontal lines ______ ______	
8. Not rotated (15 degrees) ______ ______	
9. Equal size/proportion ______ ______	
Total ______ ______	

BEHAVIOURAL OBSERVATIONS

Attitude towards testing (e.g. rapport, work habits, interest, motivation, reaction to success/failure)

Attention

Visual / Auditory / Motor problems

Language (receptive / expressive)

Physical Appearance

Unusual Behaviours / Thought Processes

Other Tests Administered

Diagnosis

WMS-R

Name____________________________

VISUAL REPRODUCTION – COPYING SHEET

Date_________________

VR I

Card A

Card B

Card C

Card D

WMS-R

Name____________________________

VISUAL REPRODUCTION – COPYING SHEET

Date________________

VR II

Card A

Card B

Card C

Card D

APPENDIX B

Content

Information for authors

- ***South African Journal for Research in Sport, Physical Education and Recreation***
- ***The African Journal for Physical, Health Education, Recreation and Dance (AJPHERD)***

Ethics committee approval

Approval from the head master of Potchefstroom Gimnasium

South African Journal for Research in Sport, Physical Education and Recreation

INFORMATION FOR AUTHORS

The South African Journal for Research in Sport, Physical Education and Recreation is published by the Stellenbosch University. Contributions from the fields of Sport Science, Movement Education, Recreation/Leisure Studies, Exercise Science and Dance studies will be considered for publication. The articles submitted will be administered by the appropriate Subject Review Editor and evaluated by two or more referees. The decision as to whether a particular article is to be published or not, rests with the Editorial Board.

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PREPARATION OF MANUSCRIPT

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The African Journal for Physical, Health Education, Recreation and Dance (AJPHERD)

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Prof GL Strydom
Bussie 494
PU vir CHO

21 Augustus 2003

Geagte prof Strydom

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Hiermee gee ondergetekende toestemming dat skoliere van ons skool genader mag word deur **mnr JA Laubscher** vir doeleindes van sy Ph.D studie.

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Hy word hiermee ook alle sterkte toegewens.

Agtend

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